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ORIGINAL ARTICLES.

Man and the Ice Age.

By Professor W. J. Sollas, Sc.D., F.R.S.

THE exact and exhaustive study of the Quaternary terraces of the Somme, which we owe to Commont, may well serve as a starting point in any consideration of this subject. In its results it is not without its surprises, for we should scarcely expect to find, as we do, that the gravels which form the earliest deposits on each of the three lower terraces all contain the remains of a "warm" fauna; the third or highest of these terraces affording *Elephas meridionalis*, the first and second *E. antiquus* and its companion Hippopotamus. Associated with these faunas are flint implements of early types. Pre-Chelléan in the third terrace, typical Chelléan in the second, and Chelléan "evolué" in the first. No signs of a cold climate are to be discovered in any of these gravels until we reach that of the first terrace, where a newer gravel is to be seen invading the older and bringing with it Acheuléan implements and the mammoth.

Although the valley of the Somme was never occupied by a glacier, yet Commont was probably justified in attempting to correlate its terraces with those of the Rhine.

At the same time, gravels with a warm fauna cannot by any ingenuity be regarded as glacial, and if those of the Somme are to be referred to the Glacial epoch at all they must be assigned to its genial intervals. But if this is true of the Somme, what is to be said of the Rhine? In answer to this I must here confess that I have never felt quite satisfied with Penck's explanation of the terraces of this and other rivers which have their source in the Alps, and long ago I had the temerity to suggest that changes of base level may also have played a part in their formation, adding that a "certain uniformity seems to prevail among the terraces and their succession in many European river valleys. To ascertain over how wide an area this extends and how precisely it is maintained, would be an interesting task for anyone with sufficient leisure to undertake it. If the uniformity should prove to be so general and exact as it seems, it would evidently point to the existence of some widely acting cause".[1]

[1] *Ancient Hunters*, 2nd ed., 1915, p. 123.

These cautious remarks have since been amply justified. In the first place an advance was made by General Lamothe, who by a careful study of the terraces of the Isser in Algeria and of the littoral deposits corresponding to them along the coast beyond its mouth, was able to show that a close accordance exists between the height of each terrace above the river and of each beach or other littoral feature above the sea. Thus the last four terraces, which alone are of interest to our inquiry, occur at 15, 28–30, 55–7, and 93 m. above the river, and the corresponding ancient shore-lines at 15, 29–32, 53, and 93 m. above the sea. It was inferred that these changes of level were due to eustatic movements of the sea and hence it was predicted that similar terraces and beaches should be met with in other Mediterranean regions and particularly in Provence.

This prediction was verified by Professor Depéret; subsequently General Lamothe, extending his observations to the Somme, was able to correlate its terraces with those of the Rhône and Isser.[1]

Thus it would appear that the view which prevailed previous to the hypothesis of Penck is the correct one; that the river terraces were not produced by the periodic melting of glaciers, but by changes in the relative level of land and sea.

We may now pass to the recent advance in our knowledge which we owe to Professor Depéret, who by a masterly analysis of the Pleistocene complex of Europe has been able to reduce its apparent discordance to harmony, and to present us with a consistent account of the events which in orderly sequence constitute the history of the Pleistocene epoch.

The key to the problem was afforded by the marine Pleistocene deposits of the Mediterranean; by making these the basis of classification the Pleistocene system has been brought into line with the other marine formations of the stratified succession, and so takes its place as the last term in the standard scale of geological chronology.

The series taken from below upwards is as follows:—

1. *Sicilian* (*Döderlein*), 90–100 *metres*.—Deposits of an ancient gulf in Sicily, now forming the "Conque d'or" of Palermo. They consist of argillaceous strata, containing a cold fauna, which accumulated at a depth of 100 metres, but are now situated at the existing sea-level. They can be traced upwards, passing into sands and conglomerates as they ascend, to a height above the existing sea-level of 100 metres, where they terminate along an ancient shore-line bordered by cliffs and sea-caves. The fauna is distinguished by

[1] General Lamothe, "Les anciennes lignes de rivage du bassin de la Somme": *Comptes Rendus*, clxii, 1916, p. 248, and *C. R. Soc. geol. de Fr.*, 18th Jan., 1918, p. 26. Professor Depéret, "Essai de co-ordination chronologique des temps Quaternaires": *Comptes Rendus*, clxxvi, 1918, pp. 480, 636, 834; clxvii, 1918, pp. 418, 979; clxviii, 1919, p. 868; clxx, 1920, pp. 159, 212; clxxiv, 1922, pp. 1502, 1594.

its richness in immigrant species, derived from the north and temperate Atlantic; these mark the advent of the first glacial episode (Günz).

2. *Milazzian* (*Depéret*), 55–60 *metres*.—Thin patches of littoral deposits, very fossiliferous, passing upwards into regular plateaux, with marine conglomerates, indicating a pebbly beach at 60 metres. Found on the peninsula of Milazzo, Sicily, and elsewhere along the coast. Fauna points to a sea sensibly warmer than that of the existing Mediterranean. Included in the stage, Mindel glaciation.

3. *Tyrrhenian* (*Issel*), 28–30 *metres*.—The well-known "*Strombus* beds", which are found all round the Mediterranean. Fauna warmer than the Milazzian, with subtropical species from the Canaries and the west coast of Africa. Included in this stage, Riss glaciation.

It may be observed here that local movements have raised these beds to 100 metres at Ravagnese in the Strait of Messina, and to more than 300 metres in the Isthmus of Corinth.

4. *Monasterian* (*Depéret*), 18 *to* 20 *metres*.—Named from the city of Monastir, Tunisia; a locality very rich in fossils. Fauna almost identical with Tyrrhenian, but on the northern coast of the Mediterranean warm species are absent. Glacial stage, Würm.

After the Monasterian the coast-line sank to its existing level, with a temporary arrest at from 6 to 8 metres.

Having established these stages in the Mediterranean, Professor Depéret proceeds to trace them along the coasts of Portugal, Senegal, the Atlantic coast of France, the Straits of Dover, and Cornwall. After discussing the deposits of Sussex and Hampshire he concludes that a broad tract of land united France and England during the Sicilian and Milazzian ages, which are represented solely by coastal plains at 60 and 100 metres.

The Tyrrhenian stage is well marked by the line of 30 to 33 metres with an associated marine and terrestrial fauna having southern affinities. The Channel then formed a great Atlantic gulf, extending as far as the estuary of the Somme but separated from the North Sea by a fairly broad isthmus. This will explain the absence of Arctic shells in the Tyrrhenian fauna of the Channel deposits.

The Monasterian stage reveals by the continuity of its marine deposits a geography almost identical with the present, and the opening of the Straits of Dover was accompanied by the introduction of a cold fauna from the North.

To account for the immigration of terrestrial animals during this stage, a new factor is introduced, that of phases of regression during which the sea sank below its existing level. These regressions are supposed to have occurred at the beginning of each of the four stages, and are said to have left well-marked traces in the Mediterranean. The Tyrrhenian beds of Sussex now at the existing sea-level and the Sicilian Forest bed of Cromer also at the existing sea-level are cited as examples in England.

An account of the discussion of the glacial deposits of the

remaining parts of the British Isles and of Scandinavia would unduly lengthen this brief abstract, and we must content ourselves with the following summary of Professor Depéret's conclusions :—

British Isles.

		British Coast-line.
Monasterian Stage. 15 to 20 metres.	Marine Terrace of 50 feet (Scotland, English Channel).	15 to 20 m.
	Glaciation of the Highlands (Würm).	
Tyrrhenian Stage. 30 to 33 metres.	Marine Terrace of 100 feet (Scotland).	33 m.
	Riss glaciation.	
	Marine Interglacial gravels of Holderness, Yarmouth, Speeton, etc. Shore-line of 30 metres, Sussex.	33 m.
Milazzian Stage. 55 to 60 metres. Pre-Milazzian regression.	Mindel (maximum) glaciation.	?
	Pre-glacial beaches of Sewerby, Gower, and Ireland.	4–8 m.
Sicilian Stage. 90 to 100 metres. Pre-Sicilian regression.	Leda myalis beds, Norfolk.	90–100 m.
	Forest bed.	6–8 m.

The scheme of co-ordination arrived at by Professor Depéret is a first attempt, and may be open to modification in detail, but the great merit of his work is to have provided us with a new and powerful method of research, the value of which is already illustrated by its results.

The uniformity which as a rule marks the level of the four marine stages over wide areas is, indeed, remarkable ; for this, however, we are not altogether unprepared, since the uniformity presented by the pre-glacial beach has long since been made known to us by the researches of Messrs. Maufe and W. B. Wright.

Returning to the marine stages as represented in the Mediterranean it will be observed that all, with the exception of the Sicilian, bear witness to a warm climate, warmer even than that now existing in that region, though the lowest stage (Monasterian) affords some indications of cold conditions by the absence of tropical shells from its deposits on the northern coast.

Thus we are presented with a striking parallelism to the terraces of the Somme, and our suggestion that the river terraces like the marine terraces are the product of genial episodes is confirmed.

At the same time evidence drawn from other sources clearly shows that these warm stages were separated from each other by glacial intervals.

We were thus led to inquire how it happens that all traces of a cold fauna are absent from the lower gravels of the Somme ?

In answer to this, attention may be called to the general absence of deposits in the intervals between both the marine stages and the river terraces. This may well lead us to conclude that the excavation

of the river valleys and the erosion of the coast proceeded continuously, as the sea-level was sinking. While this movement was in progress the remains of contemporary mammals might readily be destroyed, and, indeed, in the absence of accumulating deposits, it is difficult to see how they could be preserved. Now and then the bones of a contemporary mammal might escape destruction, and towards the end of the movement find final burial in an interglacial terrace, thus providing the investigator with one of those anomalies of distribution which sometimes prove so puzzling.

If, as Professor Depéret suggests, some or all of his stages were preceded by a regression of the sea, the surfaces exposed to erosion would be twice subjected to its action, once as the coast-line was descending, and again as it ascended to the temporary resting place which is marked by a beach or a terrace. Thus the distance worked over between the Sicilian and Milazzian stages might greatly exceed the amount given by the difference in their heights (40 metres). If, as seems possible, the sea first descended to its existing level, the amount would be given by the sum of the heights (160 metres !).

It is only during the accumulation of detritus that the necessary conditions are afforded for the entombment and preservation of animal remains.

There is an obvious and intelligible connexion between the littoral marine formations of the four Pleistocene stages and their corresponding river terraces. There is also an apparent connexion, not so readily understood, between the terraces and the great glacial moraines. Thus Professor Depéret states that the most external moraine (Mindel) [1] in the neighbourhood of Lyons is associated with the third terrace of the Rhône (50–60 m.), the next or intermediate moraine (Riss) with the second (30 m.), and the third or internal moraine (Würm) with the first (18–20 m.).

This, however, is by no means inconsistent with the interglacial age attributed to the terraces. The great mass of material of which they consist no doubt had its origin in the moraines, but between the origin of the gravel and its final deposition a long interval of time may have elapsed. Its distribution over wide areas would seem to point to a warm period when the transporting power of the rivers was enhanced by summer floods, due to the melting of the ice in its retreat.

We are now prepared to assign the recognized stages of human industry to their appropriate place in the chronological scale.

The fourth terrace of the Somme (103 metres, Lamothe), which must be included in the Sicilian, has not so far yielded any human remains.

The third terrace (56 to 59 metres, Lamothe) should evidently be referred to the warm pre-Mindel phase of the Milazzian. Its fauna

[1] This and not the Riss is said to mark the maximum glaciation ; the Riss only exceeds the Mindel in the region of the Rhine glacier, and not always there.

is remarkably similar to that of the forest bed of Cromer, and its industry is pre-Chelléan.

The second terrace (32 metres, Lamothe) corresponds to the warm pre-Riss phase of the Tyrrhenian. Its industry is typical Chelléan. The Swanscombe gravels of the Thames at 30 metres is of the same age.

The first terrace (16–18 metres, Lamothe) is warm Monasterian, and its industry Chelléan "evolué". The lower gravels are "raviné" by others of later date, which contain the remains of the cold fauna and Acheuléan implements. These evidently mark the advent of the Würm glaciation. With them may be associated the lower löss and loams, with Acheuléan implements, of the second terrace. The upper löss and loams with the upper Palæolithic industries belong to the following and concluding stages of the Würm.

This scheme seems to me to follow irresistibly from the data provided by Commont and Depéret, and similar results have been obtained by my friend Dr. Lucien Mayet,[1] though from his tabulated correlation it would appear that he regards the glacial rather than the genial intervals, as corresponding to all the periods of Palæolithic industry. I hardly think, however, that this can be the case, because in a previous publication he definitely places the Chelléan in the "Interglaciation Mindel-Riss".[2]

It is scarcely necessary to comment on the importance of the facts which Professor Depéret has made known to us and of the views which he has based upon them. They not only elucidate much that was previously obscure in our knowledge of the Pleistocene System, but they furnish us with a fertilizing idea which is certain to stimulate fruitful research in many directions: in particular into the nature and causation of fluctuations in the sea-level, a problem as important as the origin of mountain ranges —and as obscure.

Correlation of the Ibex and Jamesoni Zones of the Lower Lias.

By L. F. Spath, D.Sc., F.G.S.

In order to compare the ammonite sequence in the *ibex* and *jamesoni* zones of Pabay, recently described[3] as vitiated by faulting and dykes, with the succession in other areas, it is desirable, first of all, to give full lists of the ammonites collected on the Dorset and Yorkshire coasts by Dr. W. D. Lang and Professor D. M. S. Watson and kindly submitted to the writer for examination.

[1] Lucien Mayet, Comptes Rendus Assoc. Française pour l'Avancement des Sciences, Congrès de Strassbourg, 1920, p. 481 et seq.

[2] Ibid., Enseignment de l'année 1919–20 à la Faculté des Sciences de Lyon.

[3] L. F. Spath, "On the Liassic Succession of Pabay, Inner Hebrides": Geol. Mag., Vol. LIX, 1922, pp. 548–51.

A. Dorset Coast.

The names and numbers of the beds are those used by Dr. Lang in his stratigraphical accounts of 1913, 1914, and 1917.[1]

121 (Belemnite Stone). *Beaniceras* spp.; *Liparoceras obtusinodum* Trueman; *Lytoceras fimbriatum* (Sow.); *Tragophylloceras* aff. *loscombi* (Sow.).

120*b* (Crumbly Bed). *Beaniceras* spp.; *Liparoceras cheltiense* (Murch.), *L.* aff. *striatum* (Rein.), *L. pseudostriatum*, *L. obtusinodum* Trueman; *Lytoceras fimbriatum* (Sow.); *Acanthopleuroceras stahli* (Op.), *A.* aff. *stahli* (Op.); *A. calliplocoides*, sp.n. (= *Cycloceras stahli* Fucini[2] non Oppel).

120*a* (Pyritic Marls). *Liparoceras* cf. *pseudostriatum* (Trueman); *Dayiceras polymorphoides*, *D. langi* Spath; *Acanthopleuroceras actæon* (d'Orb.), *A.* cf. *actæon* (d'Orb.).

119 (Belemnite Shales).

2–3 ft.	below Belemnite Stone:	*Acanthopleuroceras* aff. *valdani* (d'Orb.).
3 ft.	,, ,, ,,	*Acanthopleuroceras* aff. *stahli* (Op.); *Tragophylloceras* aff. *intracrustatum* (Que.).
3–4 ft.	,, ,, ,,	*Acanthopleuroceras valdani* (d'Orb.); *A.* aff. *valdani* (d'Orb.); *A.* cf. *valdani* (d'Orb.); *Tropidoceras* ? sp.ind.
4 ft.	,, ,, ,,	*Acanthopleuroceras* aff. *valdani* (d'Orb.); *A. maugenesti* (d'Orb.).
4–5 ft.	,, ,, ,,	*Acanthopleuroceras maugenesti* (d'Orb.); *Tragophylloceras ibex* (Que.), *Tr. wechsleri* (Op.).
5 ft.	,, ,, ,,	*Acanthopleuroceras* aff. *valdani* (trans. to *maugenesti* d'Orb.).
5–6 ft.	,, ,, ,,	*Acanthopleuroceras* aff. *valdani*, *A. maugenesti* (d'Orb.); *Tragophylloceras ibex* (Que.).
6 ft.	,, ,, ,,	*Acanthopleuroceras maugenesti* (d'Orb.) and closely ribbed var., *A.* med. f. *valdani-maugenesti* (d'Orb.); *Tragophylloceras* aff. *wechsleri* (Op.), *Tr.* cf. *ibex-heterophyllum* (Que.).

[1] "The Lower Pliensbachian of Charmouth": Geol. Mag., 1913, pp. 401–12. "The Geology of the Charmouth Cliffs, Beach, and Foreshore": *Proc. Geol. Assoc.*, vol. xxv, 1914, pt. v, pp. 293–360. "The Ibex-zone at Charmouth, etc.": ib., vol. xxviii, 1917, pt. i, pp. 31–6.

[2] "Ammon. del Lias Medio dell'Apennino Centr.": *Pal. Ital.*, vol. v, 1899, p. 173, pl. xxii, figs. 2*a*, 2*b*.

118 (Upper Darker Marls).
6–7 ft. below Belemnite Stone: *Acanthopleuroceras* aff. *maugenesti* (d'Orb.); *Tragophylloceras ibex-heterophyllum* (Que.), *Tr. intracrustatum* (Que.).
7 ft. ,, ,, ,, *Acanthopleuroceras* aff. *valdani* *A.* aff. *maugenesti* (d'Orb.).
8–9 ft. ,, ,, ,, *Tropidoceras ellipticum* (Sow.), *T.* sp., *T. futtereri*, n.n. (= *Cycloceras actæon* Futterer [1] pars, non d'Orb.), *T.* aff. *masseanum* (d'Orb.), *T. galatense* (Gemm.), *T. lineatum*, n.n. (= *Harpoceras galatense* Gemmellaro [2] pars), *T. sparsicosta*, n.n. (= *Harpoceras calliplocum*, Gemmellaro [3] pars), *T.* aff. *stefanii* Fucini, *T.* cf. *subarietiforme* (Futterer), *T.* sp. ind.; *Acanthopleuroceras* aff. *stahli* (Op.); *Tragophylloceras ibex-heterophyllum* (Que.).
9 ft. ,, ,, ,, *Tropidoceras ellipticum* (Sow.).
9–10 ft. ,, ,, ,, *Tropidoceras ellipticum* (Sow.).
10–14 ft. ,, ,, ,, *Coeloceras pettos* (Que.), *C. planula* (Que.), *C.* aff. *grenouillauxi* (d'Orb.); *Uptonia jamesoni* (Sow.), *U. bronni* (Roem.); *Tragophylloceras* sp.juv.
117 (Upper Paler Marls). No ammonites.
116 (Upper Dark Band). *Uptonia* sp.
115 (Upper Pale Band). *Uptonia regnardi* (d'Orb.); *Platypleuroceras* cf. *brevispina* (Sow.), *Pl.* sp.nov. ?
114 (Middle Dark Band). *Platypleuroceras* cf. *brevispina* (Sow.), *P.* sp.ind.
113 (Middle Pale Band). *Platypleuroceras birchoides* (Que.), *P.* sp.ind.
112 (Lower Dark Band). *Polymorphites lineatus* (Que.); *Platypleuroceras* cf. *natrix* (Zieten), *P.* sp.ind.
111 (Lower Pale Band). *Polymorphites* cf. *trivialis* (Simpson), *P.* sp.ind.; *Metoxynoticeras* cf. *flavum* (Simpson) [*M. lynx* (d'Orb.), not in place].

[1] "Die Ammon. d. M. Lias v. Oestringen": *Mitt. Bad. Geol. Land. Anst.*, vol. ii, pt. ii, 1891, pl. xii, figs. 1*a–c* only.
[2] "Foss. Strati Terebrat. Aspasia": Pt. I, *Soc. Sci. Nat. & Econ. Palermo*, vol. xvi, 1884, pl. vi, fig. 19 only (non 16 = typus).
[3] Ib., pl. vii, fig. 17 only (non 11 = typus).

110 (Lower Darker Marls).
6 ft. from top: *Polymorphites* cf. *mixtus* (Que.); *Platypleuroceras* ? sp.ind.
6 ft. from base: *Metoxynoticeras* ? sp.ind.
108 (Upper "Armatus" Marls). *Gemmellaroceras* cf. *peregrinum* (Haug), *Apoderoceras* cf. *biruga* (Que.).
105 ("Armatus Limestone"). *Phricodoceras taylori* (Sow.); *Deroceras pugnax* S. Buckman; *Apoderoceras leckenbyi* (Wright).

The ammonites of the Dorset Coast confirm the Pabay sequence given in the last paper, but in addition represent the *pettos* and *Gemmellaroceras* faunas which have not yet been found in Pabay. The *ibex*-zone is also more complete in Dorset, and the whole sequence may thus be summarized as follows:—

Ibex-zone of Oppel . .	*centaurus* horizon.		[121, 120*b*]
	actæon	,,	[120*a*]
	maugenesti	,,	[119, 118*c*]
Jamesoni-zone of Oppel .	*masseanus*	,,	[118*b*]
	pettos	,,	[118*a*]
	jamesoni	,,	[117, 116]
	obsoleta	,,	[115]
	brevispina	,,	[114, 113]
	polymorphus	,,	[112, 110]
	peregrinus	,,	[108]
	taylori	,,	[105]

It should be added that the separation of a *valdani* horizon does not seem practicable, and that Dr. Lang's *carinatus* horizon [1] (= part of *centaurus* subzone of this paper) was based on a misquoted identification of its ammonite.

B. Yorkshire Coast.

"*Lytoceras* horizon": *Lytoceras fimbriatum* (Sow.).
"Extreme top of *valdani*": *Platypleuroceras* sp.ind. aff. *brevispina* (Sow.).
"Upper *valdani*," about 10 feet below last: *Platypleuroceras brevispina* (Sow.), *Pl.* sp.ind.
"Lower *valdani*," 25 feet below last: *Polymorphites trivialis* (Simps.).
"10 feet below *trivialis*": *Polymorphites* sp.aff. *caprarius* (Quenst.).

Professor Watson kindly informed the writer that his "*Lytoceras* horizon" was in bed 7 of the Robin Hood's Bay Section in the Survey Memoir.[2] It occurred "below the third continuous ironstone dogger band from the top, i.e. about 10–12 feet down".

[1] Adopted in Buckman, "Jurass. Chronol. I—Lias," *Q.J.G.S.*, vol lxxiii, 1918 (1919), p. 264.
[2] "The Geology of the Country between Whitby and Scarborough": *Mem. Geol. Surv.*, 2nd ed., 1915, p. 69.

From a comparison of the Yorkshire succession with the sequences in Pabay and on the Dorset coast it would appear that the ammonite zones of Robin Hood's Bay were misidentified, for if the "extreme top of *valdani*" already contains *Platypleuroceras* of the *brevispina* group, it must be pre-*jamesoni* in date. But immediately above is supposed to follow the "*striatum* zone", and Mr. Buckman [1] has stated that perhaps the lower part of this "*striatum* zone" was contemporaneous with the *latæcosta* subzone of Dorset. There would accordingly be no room for the *ibex* (= "*valdani*") and the true *jamesoni* beds. As yet, *Tragophylloceras ibex*, *Acanthopleuroceras valdani*, and the true *Uptonia jamesoni* have not been found in Yorkshire. A specimen labelled *A. ibex* by Professor Blake [2] is a *Tragophylloceras* of the *numismalis* group (*T. typicum*, S.B.), belonging to the lower *jamesoni* zone, and Blake's [3] examples of "*Aegoceras grenouillauxi*" (d'Orb.) are not *Coeloceras* [4] of the *pettos* subzone, but young *Apoderoceras* of the base of the Carixian. Also Simpson's *A. ripleyi*, *ignotus*, and *obsoletus* are earlier than *Uptonia jamesoni*; but Mr. Buckman [5] has recorded *Tropidoceras antiquum* (Wright) and *T. rotundum* (Futterer) from Robin Hood's Bay, and in Pabay the latter occurs just above the *masseanus* beds. ["*Harpoceras antiquum*" Wright, originally stated to have come from the *jamesoni* zone, appears to be an Upper Lias Harpoceratid of the type of *Elegantuliceras ovatulum* (Simpson).] *Beaniceras*, however, of the *centaurus* horizon or upper *ibex* zone in Oppel's meaning, also occurs in Yorkshire, together with its contemporary *Liparoceras*.[6] Mr. Buckman's "*striatum* zone" would thus have to include not only part of Oppel's *davoei* zone (for Professor Watson found *Androgynoceras maculatum* 8 feet below the "Sandy Series" at Staithes) but one or two horizons of the *ibex* and upper *jamesoni* zones below. These Yorkshire beds are unfortunately poor in Ammonites and difficult to collect from, and will require further careful investigation. So far, the succession also confirms that of Pabay.

The lower beds with *Phricodoceras* and *Apoderoceras*, poorly represented in Dorset, would probably yield interesting results if worked in detail. In Mediterranean countries, the *Deroceratidæ* are far more completely represented, and include, in addition to the ancestral *Derolytoceratids*, e.g. *Epideroceras*, gen. nov. for *A. roberti*

[1] Ib., p. 71.

[2] B.M. No. C 18115. Believed by the late Mr. G. C. Crick to be the specimen alluded to as a var. of *Phylloceras loscombi* by Blake (in Tate and Blake, 1876, p. 297).

[3] In Tate and Blake, 1876, p. 280. (B.M. Nos. C 19223–4.)

[4] The genus *Coeloceras* must be restricted to the Carixian *pettos*-group; for *A. davoei*, Sowerby, generally erroneously united with it, the new genus *Prodactylioceras* is proposed.

[5] Loc. cit., 1915, p. 97.

[6] e.g. *Liparoceras heptangulare*, Young & Bird, B.M. No. 17159, Ripley Coll.; *L. striatum* (Rein.), Tate and Blake, 1876, p. 281, B.M. No. C 18117.

Hauer[1] and allies, and *Coeloderoceras*, gen. nov. for "*Coeloceras*" *ponticum* J. v. Pia.[2] *Gemmellaroceras*, a polymorphid genus, represented only by crushed examples in Dorset, has not yet been found in Yorkshire; *Pimelites* and *Diaphorites* are unknown outside Italy, and *Amphiceras* occurs only in a few Alpine–Mediterranean localities. It is possible that some of these genera may belong to horizons of the *jamesoni* zone (s. l.) additional to those of the above sequence, but the comparable deposits of such well-known localities as Galati, Blumenstein–Allmend, Kratz-Alpe, Enzersfeld, or Agh Dagh have never been zoned in a detailed manner. This is to be regretted not only because such Alpine–Mediterranean genera as *Amphiceras* and *Gemmellaroceras* demonstrate the probable derivation from the fundamental Ammonite families *Phylloceratidæ* and *Lytoceratidæ* of the *Polymorphidæ*, *Tropidoceratidæ*, and *Amaltheidæ*, but also because an extreme application of the view that dissimilar faunas indicate deposits of different dates is likely to lead to results as erroneous as the older conception that the Mediterranean Lias was something entirely different from that of our North-West European facies.

Glaciation in South Africa, Australia, and Tasmania.

By E. J. Dunn, F.G.S.

PERUSAL of Dr. du Toit's masterly and illuminating paper on Carboniferous Glaciation in South Africa[3] suggested that some notes on the early and gradual development of data relating to glaciation in South Africa, Australia, and Tasmania by the writer might not be out of place.

In Cape Colony, the desultory and sporadic manner in which geological work was prosecuted in my time prevented any systematic or proper sequence in research. Of the fifteen years spent in South Africa, but five were in the service of the Cape Government.

Nearly all the voyaging and much of the land travelling involved were at my own expense. The three geological sketch maps of South Africa were also published at my own cost, the Governments of Cape Colony and Natal taking copies.

1870.

From about 1860 a remarkable conglomerate at Wooragee and Eldorado, near Beechworth, Victoria, Australia, excited my interest, but its glacial character was not suspected. The similar conglomerate of Bacchus Marsh was considered of glacial origin by Richard Daintree in 1866. My sketch map of Beechworth Parish was made in this year, and published by the Mines Department,

[1] "Beitr. z. Kenntn. d. Capricorn. d. Österr. Alp.": *Sitzungsb. Math.-Naturw. Cl. k. Akad. Wiss. Wien.*, vol. xiii, 1854, p. 25, pl. iii, figs. 1–3.

[2] "Üb. éine Mittellias. Ceph. Fauna a.d. N. Ö. Kleinasien": *Ann. k.k. Naturhist. Hofmus.* Vienna, vol. xxvii, 1913, No. 3, p. 353, pl. xv, fig. 2.

[3] *Transactions of the Geological Society of South Africa*, vol. xxiv, pp. 137–223.

Melbourne, in the following year. On this the extent of the conglomerate area at Wooragee was shown.

1871.

I reached Cape Town in May, and on my way to the Diamond Fields made a detour to Prince Albert and Dwyka River, Cape Colony. Here my first acquaintance was made with that most interesting and misunderstood of South African rocks then variously termed Claystone-porphyry by A. G. Bain, Trap Conglomerate and Trappean Ash by Wyley, Trap-breccia by Jones, Intrusive Trap by Dr. W. G. Atherstone, and Metamorphic Rock by R. Pinchin.

Andrew Geddes Bain, the remarkable self-taught geologist who elucidated the geology of the southern portion of Cape Colony in a marvellously accurate manner, so well and deservedly known as the Father of South African Geology, recorded observations on his Claystone-porphyry in 1845, and in 1856 traced it for 600 miles on his map published in *The Transactions of the Geological Society of London*, second series, vol. vii, pl. 21.

His worthy son, Thomas Bain, accompanied me on the detour, and showed me the Claystone-porphyry of his father; he also was thoroughly satisfied of its igneous origin. My hasty examination did not supply sufficient data to controvert his views, but the exposure on the Dwyka River showed that it was a conglomerate and not a porphyry, so Wyley's term Trap Conglomerate was adopted for the time being. At these localities the rock was hard, dark in colour, schistose in structure, and, with the containing strata, highly inclined.

Resuming my journey to the Diamond Fields, Brak River, to the south of Hope Town, was eventually reached. When the passenger mule wagon was outspanned, I noticed that the surface of the country was thickly strewn with boulders, pebbles, and angular fragments of many species of rock; these were so striated, scratched, grooved, and facetted as to prove unmistakably their glacial origin. They were derived from a widely spread conglomerate. Time did not permit me to unravel the relation of the conglomerate to the adjacent beds. Apparently, no notice had previously been taken of the peculiar features presented by this conglomerate. Before leaving the Diamond Fields in August, a rock identical with the Trap-conglomerate already seen at Prince Albert was noted on the Vaal River below Pniel.

Returning to Cape Town in September, my glacial discovery was made known and examples of the first glaciated stones found in South Africa were exhibited. Some were presented to the South African Museum in 1873. Such views, however, were considered ridiculous and preposterous, for how could glacial conditions exist in a torrid, drought-stricken region such as Hope Town?

1872.

Under instructions from the Colonial Secretary (R. Southey), I carried out a geological reconnaissance of the country lying south

of the Orange River between Hope Town on the east and the sea on the west, including parts of Bushmanland and Little Namaqualand, during the months of August, September, and October. From the Cape Town to Diamond Fields road the route diverged from Skilders Pan and thence to Prieska on the Orange River. Four troopers and a serjeant met me here, and took me on to Kenhart, their headquarters. Again my tracks crossed the Glacial conglomerate previously noticed at Brak River, and its boundaries were roughly sketched in as opportunity offered. Glaciation was especially well marked at Doornberg, even the contours of the intensely hard jasper hills were rounded and worn into beautiful curves by glacial action. Erratics strewed the plain. Perched blocks of igneous rock rested on a shelf of Doornberg jasper 150 feet above the plain.

At this period the Bushmen and Korannas were not to be trusted, and an escort was provided of fifteen troopers under Commandant Maximilian Jackson—a splendid type of man. Our transport consisted of an ox-wagon and Cape cart. On reaching Kenhart, Mr. Jackson was too ill to start, but he very kindly placed the cart and some troopers at my disposal, and we went for an eight days' tour up Hartebeeste River to Onderste Doorns, thence to Van Wyk's Vley, Groot Modder Fontein, and back to Kenhart. As the area traversed was uncharted, a rough plan was made by compass directions and cart distances reckoned at 6 miles an hour. The work closed very fairly. In this way a further slice of glacial conglomerate was sketched in.

In Bushmanland the area occupied by the conglomerate is known as the Kijan Veld. The conglomerate here is fairly horizontal. From Kenhart the whole party journeyed down as far as Pella, along the Orange River thence to Springbokfontein, Little Namaqualand, and returned by another route through Groot Vaal Heuvel to Onderste Doorns up Zak River, and I went on through Fraserburg, Beaufort West and back to Cape Town. By this trip the general trend of the wide belt of Glacial conglomerate in the northern portion of Cape Colony was determined. Owing to the great distances between water, forced marches, etc., no detailed geological work was possible.

1873.

At Grahamstown, in February, my good friend Dr. W. G. Atherstone introduced me to his Intrusive-trap near the town. He also was firmly convinced of the igneous origin of this rock, nor could I yet produce conclusive evidence to the contrary, for many years had to elapse before it became clear that my Glacial conglomerate of Bushmanland was the equivalent of his Intrusive-trap. At this time there appeared to be very great differences between the two.

My report on the Bushmanland Glacial conglomerate was published as a Parliamentary Paper in May as Geological Reports

on a Gold Prospecting Expedition, 1872, and the Stormberg Coal Field (931–73).

I visited England, and in August studied glaciation in South Wales. While at the School of Mines, Jermyn Street, London, the subject of South African glaciation was discussed with Professor, afterwards Sir Andrew Ramsay, who was favourably impressed with the evidence placed before him and the specimens brought to England.

While in London, my Geological Sketch Map of Cape Colony was published through Stanford. On this map the Glacial conglomerate discovered in 1871, and traced through Bushmanland in 1872, was indicated, but as its geological horizon was uncertain, only its area was shown under the term Glacial conglomerate, while Bain's Claystone-porphyry was marked under Wyley's term Trap-conglomerate, and an outlier shown on the Vaal River.

1874.

I returned to South Africa, and reached Durban, Natal, in April, on my way for a trip through the Transvaal and Free State. In October I observed a massive conglomerate among the hills on the north side of the Limpopo River, above the junction of Sand River, of glacial origin and no doubt of Dwyka age.

1875.

In January I met Dr. P. C. Sutherland, the Surveyor-General of Natal, at Pietermaritzburg. Up to this time I was unaware of the work done and conclusions arrived at by him in respect to the Dwyka conglomerate. He accompanied me to Verulam and Umgeni, near Durban, and showed me his "Boulder clay", the term he used for the equivalent of Bain's Claystone-porphyry. At these sites the decomposed portion of the conglomerate consists of boulders, pebbles, etc., distributed through a clayey matrix resembling the Boulder clay of South Wales. In June, 1868, Dr. Sutherland published through the Natural History Association of Natal, Durban, a description of the conglomerate, ascribing to it a glacial origin and the fact that at various localities he had discovered glacial floors beneath the conglomerate, but up to the time of our visit he had not observed any included striated stones. Dr. Sutherland was an accurate and keen trained geologist, who ranks next to A. G. Bain as a pioneer in South African geology, for previous to this time he had completed a Geological Map of Natal showing the parallel outcrops of Glacial conglomerate from north to south, and he alone of the early workers correctly diagnosed the true character of the conglomerate. January and February were spent in riding through various parts of Natal. The Dwyka conglomerate was examined at Greytown, Richmond, Ixopo, Compensation Flats, Mouth of Tugela, etc.

Returned to Cape Town in March and to London in June. While in London published through Stanford a Geological Sketch Map of

South Africa, in which the southern portion of the Glacial conglomerate in Cape Colony as well as the Natal extension was shown under the non-committal term of Dwyka conglomerate, for I was now convinced that it was not of igneous origin. There was still uncertainty as to the relation of the practically horizontal and undoubted Glacial conglomerate of the north of Cape Colony to the Dwyka conglomerate of the south and of Natal. In September returned to Cape Town.

1877.

In September, with Dr. Atherstone, of Grahamstown, I examined his Intrusive-trap at Pluro's Vale and other localities near the town, where the Dwyka conglomerate is particularly hard, dark in colour, and of great thickness. Evidence of its non-igneous origin was observed.

1878.

Sections of Dwyka conglomerate were examined at Mount Stewart, where the Graaf Reinet and Port Elizabeth Railway crosses it.

1879.

Graphite was reported as occurring at Bloed River, Cape Colony, where the railway extension from Wellington to Beaufort West was in progress under Engineer Atherstone. I was instructed to report upon it, and took the opportunity to run sections to elucidate the relations of the Dwyka conglomerate to the underlying and overlying strata, including the carbonaceous shales (Coal Measures) in which the graphite was found. Conformity of the Dwyka conglomerate with the underlying and overlying beds was established, and that above the main mass of conglomerate several distinct thin beds of conglomerate were intercalated between beds of shale, showing a gradual transition from conglomerate to shale and that the glacial conditions were gradually replaced by normal aqueous sedimentation before the carbonaceous strata were laid down. In April the report and sections were handed in ; they were published as a Parliamentary Paper, " Report on Camdeboo and Nieuwveld Coal," 1879. Section No. 3 shows the relations of the Witteberg sandstone and the Dwyka conglomerate, etc., to scale.

1883.

In April I identified Dwyka conglomerate resting upon amygdaloidal diabase at Main Road Ford, Vaal River, north of Kimberley.

1885.

I visited Australia in February, and re-examined the conglomerate at Wooragee, Victoria, that I had first observed in 1860, as I was convinced from my South African experience that it must be of glacial origin. I found abundant evidence in the way of striated, scored, and facetted stones ; particularly in material excavated in sinking a shaft behind the old Star Hotel. Examples were obtained, some were placed in the Beechworth Museum, and on the 25th others were deposited in the Technological Museum, Melbourne, where they may still be seen.

In June I returned to Cape Town, South Africa, and with Dr. Atherstone went on a trip to investigate further the Dwyka conglomerate at Matjes Fontein and Prince Albert, Cape Colony. On this occasion I discovered unmistakably glaciated stones at both localities in the Dwyka conglomerate, and for the first time obtained proofs that the Dwyka conglomerate of the south was of glacial origin and was identical and continuous with my Glacial conglomerate of the north of Cape Colony.

At Kimberley, in September, I recognized the grey conglomerate three feet in thickness found in the Standard Co.'s shaft on the east side of Kimberley Mine, resting directly upon the amygdaloidal diabase or Hard Rock of the mines, as of glacial origin, and identified it as Dwyka conglomerate forming the base of the black and coloured shales, and established these Kimberley shales as of Ecca age, and not belonging to the Beaufort horizon as Professor Green supposed. There is a remarkable parallelism between the Ecca and Dwyka strata on and near the Vaal River with those occurring hundreds of miles away south of the Karroo, as at Bloed River and Grahamstown. Although the data at Kimberley were convincing, my conclusions were strongly opposed.

In October Griquatown, Griqualand West, was visited, and the beautifully curved and rounded outlines of the hard jasper hills to the south, due to glacial action, were noted. On the return journey, at Ger's Farm, Mazel Fontein, on the north side of the junction of the Vaal and Orange Rivers, I discovered a glaciated floor, the first found in Cape Colony. The Dwyka conglomerate of this portion of the Vaal River valley was sketched in. Data obtained this year were embodied in a Parliamentary Report "On supposed extensive deposits of coal underlying the central districts of the Colony", 1886 (98, 86). On the accompanying plan the relations were shown between the Dwyka conglomerate and the overlying Dwyka Coal Measures over the whole colony and eastwards up to and including Natal.

1886.

In January I made further examination of the Dwyka conglomerate near Grahamstown, with Dr. Atherstone, and in April left South Africa and returned to Victoria, Australia.

1887.

Glacial deposits at Rutherglen, Wahgunyah, Springhurst, and Eldorado were mapped for the Mines Department, Melbourne, in May.

"Notes on the occurrence of glaciated pebbles and boulders in the so-called Mesozoic conglomerate of Victoria" was published in June in the *Transactions and Proceedings of the Royal Society of Victoria*, vol. xxiv, pp. 44–6.

A second edition of the *Geological Sketch Map of South Africa* was published through Sands and MacDougall, Melbourne, on which the Dwyka conglomerate as far as then known was marked.

1888.

Glacial conglomerate noted at Egerton and Gordon, Victoria, in May, and at Tarrawingee and Badaginnie in June.

1889.

Commenced mapping the Glacial conglomerate at Wild Duck Creek, Derrinal, and at Heathcote, Victoria.

1890.

Mapping of Glacial conglomerate at Derrinal and Heathcote continued at intervals. In February examined Bacchus Marsh Glacial conglomerate. A paper on "The Glacial conglomerates of Victoria" was published in the *Transactions of the Australian Association for the Advancement of Science: Melbourne Meeting* (vol. ii, p. 452).

1891.

Both north and south of the railway at Derrinal extensive areas of Glacial conglomerate were mapped. Numerous erratics of large size were located, and abundance of beautifully glaciated boulders were found. Fine examples were obtained for the Geological Museum collection, Melbourne. A well glaciated floor—the first in Australia—was discovered. The late Dr. Howitt, then Secretary for Mines, kindly took photographs at sites I selected during the survey. Reports, plans, and illustrations were handed in in August.

1892.

"Notes on the Glacial conglomerate, Wild Duck Creek" was published as a Special Report by the Department of Mines, Melbourne. It aroused wide interest in glacial phenomena in Australia, and directed attention to glaciation generally. Subsequently, abundance of glaciated stones, floors, etc., were found at Bacchus Marsh and elsewhere.

In October work took me to Lake Rolleston, on the west coast of Tasmania. The late Mr. T. Moore, one of the sturdy pioneers of that exceedingly rough and difficult country, acted as guide, and as we trudged through the mud and scrambled through the "horizontal" scrub he related how some remarkable rocks at the lake had puzzled him very much, but I was not prepared for the grand terminal moraine, covering hundreds of acres and attaining to a thickness of as much as 250 feet, that disclosed itself on nearing the lake. This wonderful accumulation of heterogenous material, including rock masses the size of houses, is a finer example of a terminal moraine than I saw in Switzerland. Everything about the moraine was so fresh looking that its age could only be Recent or Post-Pliocene at the most. Large and small glaciated stones abounded. Massive Devonian conglomerate on the sides of the glacier was ground, grooved, and polished where impinged upon by the moving ice, as at the bend I named Moore's Shoulder. Roches moutonnées, grooved and polished floors, and striated

rock surfaces were found to be common along the former course of the moving ice. Several of the most prominent groups of erratics were located and named. Probably the inaccessible nature of the country accounted for this remarkable development of glaciation having previously escaped notice.

Mr. Moore was delighted to learn the true character of this strange jumble of rocks, and enthusiastic when the various glacial developments were explained to him, and, later on, he made good use of his knowledge by greatly extending the areas of glaciation on the west coast.

On the same trip, I also discovered between Mount Reid and Moore's Pimple a much older Glacial conglomerate, containing scored, striated, and facetted material. It corresponded in character and geological horizon with the Derrinal conglomerate of Victoria and Dwyka conglomerate of South Africa, thus furnishing an excellent common bench mark in each country.

1893.

A paper on "The Glaciation of the Western Highlands of Tasmania", describing the above, was published in the *Proceedings of the Royal Society of Victoria*, vol. vi, pp. 133–5, with plan, pl. viii, 1893. The plan of the Heathcote conglomerate areas was handed in to the Mines Department, Melbourne.

1897.

In November, while examining the Silver Star Mine, near Stanthorpe, Queensland, I heard of an outcrop of coal at Ashford, Severn River, across the border in New South Wales, and paid a hurried visit to the locality, where features of great interest presented themselves.

Beneath a thick seam of coal, and separated from it by only a few feet in thickness of shales, etc., was a well-marked Glacial conglomerate, the included pebbles scored, striated, and facetted, especially at Fraser's Creek Station. An abundant *Glossopteris* flora occurred in the shales intervening between the conglomerate and the coal.

Shortly before this, D. Draper and others reported the occurrence of coal seams near Johannesburg, South Africa, with conglomerates beneath them, which was termed "Boulder clay", and which seemed to me probably to represent the Dwyka conglomerate. This conglomerate appeared to supply the necessary data for linking up the Ashford conglomerate of New South Wales with the Dwyka conglomerate of South Africa and with the Derrinal conglomerate of Victoria, all being of glacial origin and associated with a *Glossopteris* flora. At Cherry Gully and Silver Wood Rail Stations, Queensland, Glacial conglomerates were noticed on a hurried trip, and considered as probably of the same age as the Ashford conglomerate, but this appears to be doubtful.

A short paper calling attention to this Ashford conglomerate was

published in the *Proceedings of the Royal Society of Victoria*, vol. x, new series, pp. 204–8. A photograph of a glaciated pebble from this locality was later published in my book, *Pebbles*, 1911, pl. 52, fig. 2.

1898.

The discovery of glaciation at Ashford was not only met with the usual incredulity, but was flatly contradicted, for in the *Records of the Geological Survey of New South Wales*, 1898, vol. vi, p. 80, under the signatures of T. W. E. David and E. F. Pittman, who visited Ashford in June, appears the following statement :—

"After a careful search we were unable to discover the least trace of glacial action in these beds."

Although separated by thousands of miles of distance, the parallelism of the geological conditions existing at Ashford, New South Wales, and Vereeniging, South Africa, is remarkable, and these two sites appear to afford special facilities for establishing a common geological horizon for both countries.

In June a visit was paid to Europe, and glaciation studied in Switzerland at Chamounix, Rhone glacier, and many other places.

1899.

Returned to Australia via South Africa, as I wished to examine the conglomerate underlying the coal seams in the Transvaal. At Vereeniging this conglomerate was identified as glacial and as the continuation of the Dwyka conglomerate. The *Glossopteris* flora in the shales between the coal seams and the Glacial conglomerate is much older than the flora found with the Stormberg coal.

Previous suggestions were confirmed, and the geological conditions at Vereeniging were found to bear a striking resemblance to those existing at Ashford, New South Wales.

In addition, the whole circuit of the Dwyka conglomerate and adjacent Coal Measures of South Africa was completed.

1900.

Data obtained the previous year were published with a plan in the *Transactions of the Philosophical Society of South Africa*, vol. xi, part i, March, 1900. Much opposition was expressed by local geologists to the views therein set forth, but with minor exceptions they have been verified and are now generally accepted.

1911.

Along the southern coast-line of Victoria, especially to the westward of Western Port at such localities as Grantville, Hurdy-Gurdy Creek, Wonthaggi, Inverloch, French Island, and elsewhere, pebbles of unusual character occur. They are in different stages of rounding and of many varieties of rock, such as chert, agate, jasper, silicified wood, quartzite, lydianite, quartz, etc. Altogether, the facies of the pebbles appear to have more affinity to the pebbles on the north coast of Tasmania than to those found further inland in Victoria. Near Grantville well-rounded quartz pebbles are chiefly

met with in thin beds of gravel and at elevations 150 feet or more above sea-level. Near Inverloch, pebbles of the peculiar hard cherty rock often found associated with the Older Tertiary basalt are common. At Hurdy Gurdy Creek many varieties of siliceous rock are met with. Of special interest is the fact that so many of these pebbles are not only well rounded, but highly polished; precisely the same as those found in glacial deposits. Unless polished by glaciation, their condition cannot be accounted for, and although some, as near Grantville, have certainly been deposited by water, they could not have undergone much attrition without removal of the polished surface.

This evidence is further buttressed by other facts, for one example in my possession of the cherty grey rock from Inverloch bears scratches and polished marks that are indisputably glacial; others were observed carrying similar evidence.

There is no room for doubting the glacial character of the pebbles, and as there are no corresponding pebbles further inland the question arises as to the source from which they were derived. That they came from a southerly direction appears most likely, and bearing on this is the remarkable abundance of small sapphires in most of their varieties, always extremely well rounded unless again split up, found in the valley of Bass River, also apparently having no source in a northerly direction.

Post-Pliocene glaciation was developed on a grand scale on the west coast of Tasmania, and these glacial pebbles are in Post-Pliocene or Recent deposits. On the whole, it appears probable that these polished pebbles came from the direction of Tasmania, and that they are a fringe from the latest glacial developments in that island, such as occurs at Lake Rolleston. Then arises the question: Have they travelled overland or by water? And here the question as to the age of Bass's Straits obtrudes itself. That land communication may have existed well into the Recent period is proved by the trial bore I had drilled at Sorrento, Victoria. The material from this bore, according to Mr. F. Chapman, shows that a subsidence of 800 feet has taken place there during the Recent period, as proved by the fossils. Since the deepest part of the Straits is only about 200 feet, it is quite possible that land communication between Victoria and Tasmania existed even to the time when the aborigines of Australia migrated to its then extreme southern extremity.

These polished pebbles may yet furnish valuable testimony as to the period at which Bass's Straits was formed, or perhaps begun, for they are still uncompleted. These pebbles well deserve more attention than has so far been bestowed upon them.

In notes on French Island, published in *Records of the Geological Survey of Victoria*, vol. iv, part i, pp. 59–64, mention was made of them.

The Physiography of South-West Cornwall, the Distribution of Chalk Flints, and the Origin of the Gravels of Crousa Common.

By Miss E. M. Lind Hendriks, B.Sc.

Deposits of Newer Pliocene Age.
Types of Valley in South-West Cornwall.
I. *District east of Porthleven.*
Evidence of superseded drainage system :—
A. Wendron district and Helford River.
B. River Cober.
C. The Loe and Lizard.
Conclusions.
II. *District west of Porthleven.*

A CONSIDERATION of some unexplained physical features of both Devon and Cornwall does not hitherto appear to have been regarded as a line of approach towards various problems of Devono-Cornish geology still awaiting solution. Although the attempt is not yet by any means advanced, the results so far obtained appear of sufficient interest to communicate.

The influence of the uplift of the Pliocene platform upon the scenery in steepening the lower part of the valley slopes while deepening and cutting back the larger valleys has been described by Mr. Barrow (1) [1] :—

> " This feature becomes less marked as the valleys are ascended, and in the case of the River Camel it disappears altogether at a distance of 22 miles from the sea. Above this point the river-banks and also the ground above them, now much over 430 feet high, retain in the main the same angle of slope which they had in Pliocene times . . . the retention of the characters of the older scenery is naturally most marked in the still higher ground; "

while the origin of some gorges from the same cause has also been described by Mr. Dewey (2), who indicates also the rejuvenating effect of river-capture. Beyond these, little information has been found, except for one brief statement (3) : " The river system of Devon and Cornwall is obviously epigenetic but so complex and intricate in its character that it has hitherto defied explanation " (3) ; and Dr. Flett expresses in two sentences (not seen until this paper was roughly completed) the outline, of which this is an attempt to fill in the details :—

> " . . . in early Pliocene or Miocene times this district (south-west Cornwall) stood for a very prolonged period at a somewhat lower level than it does now, and the agencies of denudation, acting very slowly but with irresistible force, planed it down to a flat surface which rose very little above sea-level. Subsequently, the land gently sank and the final smoothing of the plateau was achieved by the waves of the Pliocene sea " (4).

[1] Numbers in brackets refer to bibliography at end of paper.

With regard to the distribution of Chalk-flint and Greensand chert, Mr. Clement Reid wrote in 1904 (5) :—

> "So far as we know, there is no reason to suppose that any Eocene outlier still exists in the county, but the curious localization of an extensive deposit of angular Chalk-flints at Ludgvan, and the occurrence of a mass of beach-pebbles of the same flints to the leeward at Gunwalloe" (and Loe Bar) "convince me that an Eocene outlier is preserved, or lately existed, under the sea not far from St. Michael's Mount . . . but whether this Eocene gravel is a mere isolated patch or no is not clear" (5).

In this connexion the equal abundance of such pebbles in the shingle of Kennack Sands, Maen Porth, Swanpool, near Falmouth (13), and the creeks of Helford River (13)—all on the opposite side of the Lizard Peninsula—is not stressed. The process of evolution of the existing topography appears to link these facts together.

Types of Valley in South-West Cornwall.

The history of the scenery is read in the slopes of the valley-sides. In West Cornwall the valleys are of several distinct types :—

1. The ordinary V valley with straight slopes and interlocking spurs. This is characteristic of the Hayle River and smaller streams in the district west of Porthleven.

2. The V valley incised within slopes of earlier date and grading with a point either (*a*) above or (*b*) below sea-level. To the (*a*) class belong the valleys about Kennack Bay ; the (*b*) class includes the Loe Valley and part of the Helford River and its tributaries on both banks. The upper and earlier slopes are often somewhat hollowed.

3. The district east of Porthleven is characterized by the occurrence of wide, steep-sided valleys, with a small stream meandering over a flat floor. Such are the Gunwalloe and Poldhu valleys, which appear disproportionately large and deep for their surroundings ; the Cober, in the neighbourhood of Lower Town ; and the Porthleven valley, between the harbour and the Helston-Penzance main road. The last named contains a less sluggish stream. Valleys of this type rank among the oldest topographic features of the district, and have a similar history. The ancient St. Ives-Mounts Bay valley-strait is of somewhat similar type, and it is remarkable that portions at least of all these are parallel with one another. This point will be returned to later. They have functioned alternately as river-valleys and creeks, for their middle slopes are usually rounded in a manner suggestive of ancient cliff-lines. A pair of these features is traceable one above the other more or less continuously around the coastal valleys from Marazion, through Helston, almost to the Lizard. The older of these is probably newer Pliocene, for the lower and younger one is regarded as the oldest Pleistocene cliff because it is associated with the Raised Beach of that age (10). There are everywhere indications in the valleys

of the existence of once larger streams, probably during the period of increased precipitation which heralded the formation of the northern ice sheet.

4. Connected with valleys of type 3 on the one hand, and on the other with a hollow of very gentle gradient crossing the Pliocene plain, there occurs in several localities, to which reference will be made, a rounded, funnel-like groove with unusually steep gradient. These groove-like hollows are usually dry and hang, as a rule, several feet above the level of the main stream, into which they invariably run at an angle. They appear to be connected with drainage changes of an ancient date, and are for present purposes designated " reversal hollows ".

5. Hanging valleys are frequent along the coast between Porthleven and Marazion, but the coastal drainage of the Tregonning granite mass is of a peculiar type. Usually the smaller valleys are those which hang, but between Tremearne and Prah sands are several deep valleys, of which Trequean is the largest, with U section and winding course. Sometimes the floors have been left hummocky by the old tinners, for they are generally rich in stream tin. Trequean hangs at nearly 100 feet to the cliff edge, contains the merest trickle even after winter storms, and has a conspicuously rounded crag at its mouth.

From what follows it will be seen that with the peeling off of the Mesozoic sediments the granite masses tended to set up mutually interfering systems of radial drainage. Evidently the type of valley with which we are here dealing functioned at one period as overflow channels from the melting snowfields of Tregonning and Godolphin Hills.

At Perranuthnoe the valley hangs to a 40 feet cliff of stiff mud or clay, in which are embedded occasional layers of angular fragments of local material.

All these fragments have their long axes placed horizontally, and there also occur at various levels rounded boulders of transported material of varying sizes, but always in accordance with the bedding, and horizontal. Like the loam of Prah sands (11), it also contains much vein quartz, but it differs fundamentally from that deposit in containing evenly bedded layers of transported material. It also differs in this, and in the stiff, clay-like matrix, from the normal " head " which overlies it. Its relation to the older Pleistocene Raised Beach is not altogether clear, for at the Greeb, near Perranuthnoe, is a section where the clay rests upon greenstone, suggesting that the notch of the old beach is cut into it, the angle of the notch being clay and its base greenstone. From the ancient beaches connected with the two degraded cliff-lines above, the boulders in the clay may have been derived. The survival of such a cliff on the Atlantic coast has long been an enigma, to which a solution is here offered.

I. District East of Porthleven.

Evidence of superseded drainage system :—

A. Wendron District and Helford River.

The River Cober rises near Carnmenellis, and flows south-south-east down an open and, in places, marshy valley to Porkellis. Here, having fallen 50 feet in 1½ miles, the valley, now at 400 feet, turns south-west. There is here every indication that the drainage formerly proceeded in a south-easterly direction, and marshy

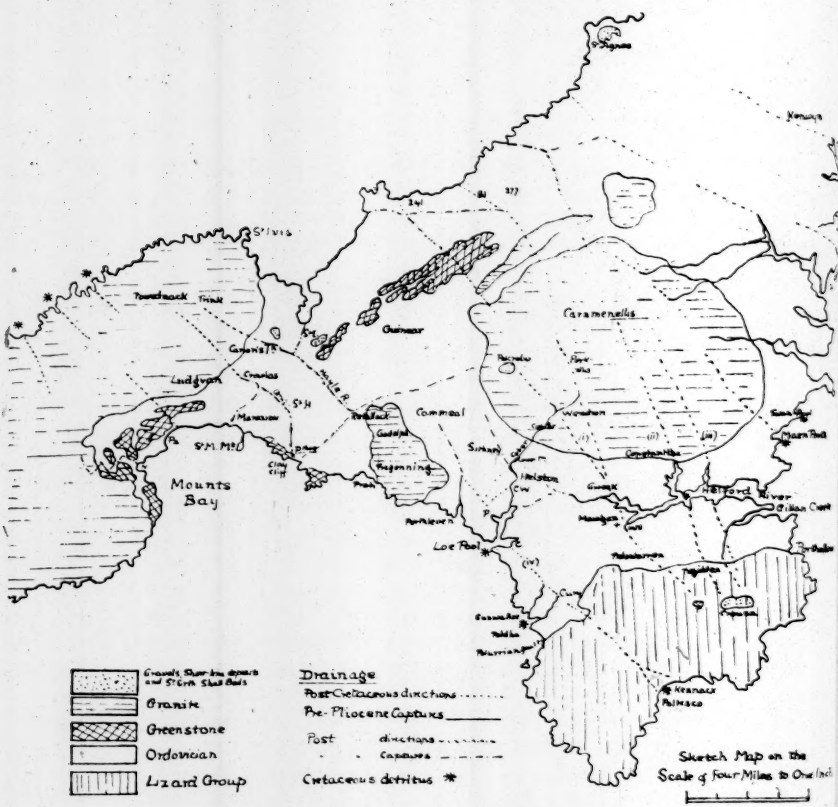

Fig. 1.—Geological sketch-map of South-Western Cornwall.

depressions sloping gently towards the Cober cut the watershed and lead into the rapidly steepening valleys heading towards Constantine and Gweek. A view-point above Trenear, near the Falmouth main road, shows Crousa Common in the direct continuation of these. Moreover, on the south side of the Helford River, near Mawgan, the Trelowarren valley enters from the south-east, and the higher

(i.e. earlier) slopes of it above the incised V, when viewed from the south, die out in a north-westerly direction, so that their base must have a gentle gradient towards the south-east antagonistic to the slope of the present valley-floor. The latter dies away into a gentle hollow, which, grading with the upper slopes, crosses the country towards Traboe in a south-easterly direction. This is well seen from a view-point to the west of St. Martin's Green. From other view-points to the east of this a similar history can be traced through Constantine on the north side of the Helford River and Tregidden on the south of it. It seems that the river which once flowed across from Carvedras or Edgcumbe to Crousa Common was intercepted in two places, near Groyne Point by the Helford River itself and near Tregidden by the Gillan branch of it.

In the district east of Constantine, particularly about Trewoon, are flat-topped marshy spurs and flat marshy hollows at about 300 feet O.D. These occur as finger-like extensions of some plain amongst the higher ground, and a probable explanation of such features appears to be that they are the relics of graded valley-floors and date from a pre-Pliocene period when the sea stood at about the present 200 ft. contour. Such dissected flood-plains form conspicuous features in the scenery of parts of South Devon.

It should further be noted that the tributaries on the north bank of the Helford River occupy larger valleys, notwithstanding the hardened rocks of the metamorphic aureole surrounding the Carnmenellis granite, than those on the south ; and a series of small valleys on the south bank tend to hang. One of these occurs just to the north of Mawgan Church. It appears that the Trelowarren stream formerly entered the Helford River at that point before it was intercepted between this and the mills.

B. The Cober.

At Trenear the stream develops a tendency to entrench itself, but a gentle gradient is maintained, still in a south-westerly direction, to Coverack Bridges. So perfectly graded are the upper slopes that the notch of the modern valley is concealed at even a few yards' distance. This feature dies out at nearly 6 miles from the sea.

Below Coverack Bridges the valley-floor suddenly drops something like 250 feet in a distance of less than half a mile in a series of cascades over the granite margin, the gradient here changing from about 1 in 160 to 1 in 10. It then resumes its former gentle gradient at 50 feet O.D., the valley having as suddenly opened out into an impressive, deep, flat-bottomed one with precipitous sides, as described under type 3 above. In this connexion it is of interest that although in the valley of the Lyd in Devonshire the first sign of the metamorphic aureole of the Dartmoor granite causes a waterfall (at Kits Steps) (6), here the Cober meanders over the entire belt of contact-altered killas. Below the viaduct as far as Lower Town the meander-belt runs due west, turning south-

west again as the Sithney tributary enters from the north-west. Just above Helston the valley narrows, making a nearly right-angled turn to the south-east, cutting right through the strike of several short belts of greenstone which might, apparently, have been avoided. Opposite the bend, crossing the Penzance main road, is one of the features of type 4 above. The course is then south-west again to Castle Wary, but here, opposite another feature of type 4 near the Porthleven Road, the valley bends once more to the south-east, then south, and so enters

C. Loe Pool,

the general trend of which is nearly south-west. The first of these "hollows" enters a shallow depression, not containing a stream, which crosses the county in a south-westerly direction and dies out near the head of the Penrose Creek of Loe Pool. This creek is of type 2, and trends south-east. In the south-east angle of Carminowe Creek (*C* on map) is a small, steep hanging valley, which opens into another shallow depression. This ultimately merges, south-eastward, into the upper part of the Gunwalloe stream (at Berepper). The valley is here of type 2, but at Chepye a right-angled bend occurs, and the south-westward valley from here to the sea at Gunwalloe Church Cove is of type 3. South-east of Chepye the slopes indicate an ancient valley passing to the west of Cury, and continuous with the upper portion of the Poldhu stream. The latter at this point makes a right-angled turn in a valley of type 3, and continues south-west nearly to the sea at Poldhu Cove. Crossing the Lizard main road south of Bonython is a shallow south-eastward depression connecting the head waters of Poldhu with those of Kennack and Poltesco, where the valleys reaching the sea are of type 2*a*.

Conclusions.

It thus appears that in south-west Cornwall there are preserved fragments of an ancient and now almost completely superseded drainage system :—

(i) Through Porkellis, Gweek, and Traboe towards Crousa Common.

(ii) Through Edgcumbe, Constantine, and Tregidden towards Crousa Common.

(iii) Over Long Downs, Trewoon, and Tregidden, towards Crousa Common.

(iv) From the Tregonning granite-mass, possibly joined by a stream from Carnmenellis, right across Penrose and Carminowe creeks to the sea at Kennack and Poltesco.

The course of (iv) indicates a former further westward position of the coast-line in the comparatively soft sedimentaries between the Lizard rocks and the Tregonning granite. The graded nature of the ancient valley-floors (see figure 1) also demands sea-level at about the present 200 ft. contour, as indicated by the shore-line deposits of probable Mio-Pliocene age at 180 feet, near Canon's Town (4, 7). The rise of the Pliocene sea rejuvenated the coastal

drainage, and captures occurred near Cury (Poldhu stream), Chepye (Gunwalloe stream), Loe, and Porthleven. The breaking up of the ancient river in its fullest region accounts for the disproportionately large coastal valleys at the first two of these four localities. The Polurrian, Mullion, and Kynance streams working back along fault fissures in the harder rocks had not time to effect captures before the Pliocene submergence was upon them.

In the Loe valley further interceptions occurred at Castle Wary and Helston, checking the growth of the Penrose Creek by diversion of the drainage into the main valley. Energy was therefore concentrated upon the re-grading of the Cober valley, which has now been accomplished for a distance of nearly a mile above the site of the capture (see figure 1). Rejuvenation, however, extends to a point near Trenear, where the interception of the headwaters of (i) more recently took place.

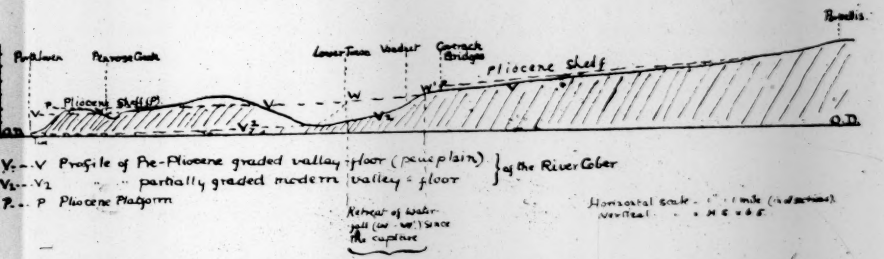

FIG. 2.—Profiles of the ancient and modern valleys of the River Cober.

Of greater importance is the great parallel intercepting line of the Fal below Truro, and its branch, the Helford River and Gillan Creek. The trapping influence of belts of disturbance upon the drainage is well known (8, 9), and the Helford River has worked its way back rapidly due west through such a belt, and trapped the larger rivers (iii), (ii), and (i), one after another, not at their headwaters, but near their region of maximum volume near Gweek, Groyne Point, Helford, and Tregidden or Manaccan respectively. Therefore, the Helford River has a valley of greater depth than that of the Cober to-day.

The valleys (i), (ii), (iii), and (iv) thus indicate an original south-easterly slope, and belong to the peneplain produced by post-Cretaceous drainage working through pre-Pliocene time. They are, therefore, a relic of the drainage consequent upon the post-Cretaceous uplift, and are comparable with the similar relic of South Wales, where corresponding intercepting lines of drainage, trapped by belts of disturbance, play an analogous rôle (8). And further, the directions of all these intercepting lines may be compared with the general trend of the two great ones constituted by a part of the Lower Severn and the Bristol Channel respectively. In this connexion the position of St. Agnes Beacon is suggestive.

On account of the pre-Pliocene drainage changes of West Cornwall, the Cretaceous detritus brought down by the original streams was deposited. It underwent little disturbance at the ultimate depth of water, approximately 21 fathoms, over the Lizard Peninsula during the 430 feet submergence of older Pliocene time, and so was not further abraded or re-arranged until the retreat of the sea during the elevation of the Pliocene platform. Chalk-flints, therefore, survive in the beaches of Loe Bar, Gunwalloe, Kennack, Swanpool, and the creeks of Helford River to-day.

The gravels of Traboe and Crousa Common, which rest on the present watershed of the marine-trimmed peneplain, and consist of the hardest and most durable rocks derived from the granite and Palæozoic area to the north, represent either the combined mouths of the ancient Carnmenellis drainage before the Helford system was in being, or a corrom or watershed-delta deposited as a result of the Helford captures.

Chalk-flints have not yet been discovered in the gravels, but these, being the earliest detritus, would be expected, if at all, only at the base, which is not at present exposed. Corroded Chalk remnants may, however, be represented by the clay in the deposit.

The gravels, therefore, are a further indication in this district of the part that may be played by the beds of ancient rivers once practically at base-level. These having been cut into by younger scenery, now occupy the highest part of the present divide, which is rendered even higher by the very fact of their presence, because they afford a protective capping to the gabbro which has therefore in that area been unusually resistant to the differential denudation meanwhile in progress elsewhere, a process under which the comparatively soft sedimentaries of the Helford Basin have been affected most.

As the gravels were only under a very few fathoms of water in Pliocene time, the folding in their upper portion may be in part due to re-arrangement by wave action. It is anticipated that the Polcrebo gravels may prove to be a similar deposit resulting from drainage changes, and also that a similar history may be traced around other granite masses of both Devon and Cornwall.

With the re-exposure of the land during the elevation of the 430 ft. platform, which began in later Pliocene time, the streams for the most part found and deepened their previous valleys, sweeping out the light sediments and emphasizing the pre-submergence changes which have now become, through long accentuation, the dominant features in the topography. Post-Pliocene drainage is, however, represented by the Hayle River, the upper portion of the Porthleven stream, the Sithney tributary of the Cober, and in the harder rocks of the Lizard Peninsula by such smaller features as the Ryniau and Polcornick hanging valleys. It seems that the Gwinear-Carnmeal Downs Strait, which nowhere exceeds 300 feet O.D., emerged from the sea in the form of a flat-bottomed

valley, and the drainage falling on the adjacent granite slopes collected in the light sediments in two streams on either side of this. Thus originated the upper part of the Porthleven stream and the Sithney tributary of the Cober (see figure 3).

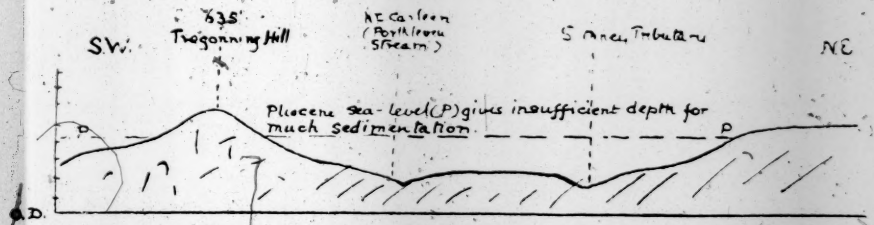

FIG. 3.—Initiation of two post-Pliocene streams in the light sediments at either side of the flat-bottomed (Gwinear-Carnmeal) strait-valley. V.S. = H.S. × 7.

Lastly, the submerged forests of the mouths of the Porthleven and Helford Rivers indicate the recent date at which these valleys were drowned. (A downward movement in South Wales of at least 30 feet is known to have occurred in post-glacial times) (12).

II. Note on the District West of Porthleven.

The drainage of the Land's End district, the higher part of which was an island during the Pliocene submergence, preserves the ancient south-east tendency, and the Ludgvan Chalk-flints appear to be a deposit from post-Cretaceous streams draining into the St. Ives-Mount's Bay Strait. In this connexion, it is significant that the raised beaches in which Chalk-flints occur lie at the mouths of river valleys (marked * on map). Some of the drainage features of this area are peculiar, and the solution offered by figure 4 fits in with all the

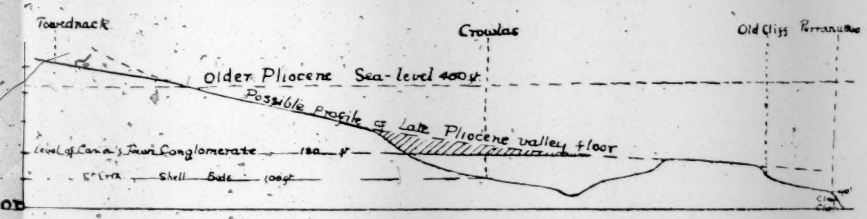

FIG. 4.—Trendrine Hill to Perranuthnoe. The wedge-shaped shaded area represents the amount of sediment postulated to fill up the strait. V.S. = H.S. × 13·2.

facts. If the shore-line deposits at 180 feet near Canon's Town are, in part, of pre-Pliocene age, it is conceivable that by the 430 feet submergence during Pliocene time the strait became levelled up by sediment, which pushed out the coast-line further north and south. On the withdrawal of the sea, post-Pliocene streams from Trendrine and Trink Hills, following the earlier (south-east) direction of the older and upper part of their valleys, flowed across, the latter

through Canon's Town towards Retallack Mill, the former grading with the higher and older of the two ancient cliff-lines in the neighbourhood of Perranuthnoe. This either became deflected to the south-west by the comparatively soft bed of the newly-exposed strait, or was captured by a small coastal stream rapidlyworking back through the soft deposits. This would account for the disappearance of the higher and older cliff-line between Marazion and Penzance. A similar capture by a northward coastal stream occurred about half a mile south of St. Erth. In the non-metamorphosed rocks south-east of St. Erth the reversed drainage worked back and tapped a Carnmenellis-Perranuthnoe stream at the "elbow" near Retallack. Hence the drainage became established on the Hayle side, and the valley above Canon's Town is little steepened. In the Trendrine case, however, the reversed drainage cut out the now dry valley near St. Hilary, and the valley north-west of Crowlas has been rejuvenated. Both the Trendrine and Crowan or Carnmenellis streams were laden with mud from the beds of the two straits—St. Ives Mount's Bay and Binner Downs respectively—and all this mud was deposited near Perranuthnoe in a delta beneath the cliffs when the captures occurred. As the sea gradually receded, this mud was uncovered, and while yet more or less liquid the layers of angular fragments of local rock became from time to time embedded in it. With exposure it gradually hardened, and is now once more yielding to the sea.

The River Hayle, therefore, is compounded of three distinct elements, and is one of the youngest features of south-west Cornwall. Its course, generally speaking, combines three directions: that of the coastal pirate-stream, more or less parallel with other intercepting lines already noticed; a direction inherited by the middle portion from an earlier tendency; and the north-eastward trend of its upper part. The Lizard boundary faults at Polurrian and Porthallow trend north-east and south-east respectively; and these are also the directions of strike of the two main masses of greenstone in the Land's End district (10). Each mass constitutes "a much broken, sheared, and disturbed belt" (10), and the two greenstone lines converge near Newlyn. The course of the Newlyn River from about half a mile west of Nancothan to the sea is a series of rectangular bends combining the same two directions. This behaviour may be a piece of evidence the geological value of which has not been recognized, for it is further noticed (10) that "all the outcrops, including that of the granite, are at Newlyn shifted considerably to the west, but *no clear evidence* of this disturbance can be obtained, for the border of the granite between Newlyn and Nancothan is obscured". A plea is here lodged for the claims of physiography in such cases.

Beach Deposits of Newer Pliocene Age at Helston and Porthleven.

These deposits are of very limited extent, occupying only a few square yards in each case, but they are of interest on account of their association with the higher and older of the two widely distributed features which may now with certainty be ascribed to ancient cliff-lines.

The Porthleven exposure is the best, and occurs in a quarry and road-cutting at 160 feet O.D. half a mile north-west of Porthleven Harbour, in the by-lane to Methleigh, a few yards below the road from Porthleven to Rinsey Croft. The quarry shows a few feet of killas with granite veining resting on greenstone. In one corner the killas has thinned away, leaving a greenstone platform on which rests an accumulation of coarse sand alternating with rounded pebbles, the whole banked steeply against the greenstone. The pebbles appear to consist chiefly of altered greenstone, and vary in size from small grains up to about 3×2 inches, the latter being the most numerous. They were not unduly tampered with, owing to the limited extent of the deposit, which is even now almost obscured by "head". No traces of fossils were obtained. At the thickest part, the section comprises :—

Soil ..... 3 ft.
"Head" .. 2–3 ft.
Beach .... 3–4 ft.
Greenstone surface.

The road section shows steeply bedded sands and fine pebbles.

The Helston deposit is similar and occurs at a little over 100 feet O.D. at the foot of the ancient cliff on the Penzance main road near the bridge on the north-west side of the town.

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Some Points in Sedimentary Petrography.

By R. H. Rastall, Sc.D., M.Inst.M.M., F.G.S.

FOR several years prior to 1914 the writer was engaged in the study of the mineral composition of loose detrital sediments with special reference to the rarer minerals and so-called heavy constituents of sands, the principal object of these investigations being an endeavour to ascertain what conclusions, if any, could be drawn as to the source and past history of the material and their bearing on stratigraphical and palæogeographical problems along the lines laid down by Dr. Thomas in his well-known researches on the New Red Sandstone of south-western England.[1] In those days the subject was still in its infancy, and there were no standard books of reference dealing with it, such as are now abundant: it was necessary to evolve methods and to learn the characteristics of the minerals in grains by experimental investigation and by reference to the comparatively few published descriptions then available.[2] This work was carried out chiefly on the Lower Greensand between the borders of Buckinghamshire and the Wash, but a good deal was also done on the superficial deposits of the neighbourhood of Cambridge and elsewhere, and some of the results obtained on the last-named group were published.[3] The study of the Lower Greensand was, however, still incomplete at the end of 1914. After the war, for reasons unnecessary to detail here, it was not possible to continue the investigation of this particular formation on a more extended scale, as had been originally intended, and the results attained up to 1914 were published in the Geological Magazine.[4]

During the war the study of sedimentary petrography underwent great development at the hands of several workers, especially Professor Boswell, and results of great value were attained, largely on the economic side, in its application to glass-making, refractories, furnace-linings, moulding-sands, and many other technical uses. Nevertheless, it will doubtless be generally admitted that there is room for improvement both in methods and in the interpretation of results in their bearing on scientific petrography and the general problems of geology. The writer, therefore, ventures to think that one or two points arising from his earlier and largely unpublished work may be of some small value in this connexion. In furtherance of this idea the following somewhat discursive notes have been put together for what they are worth.

[1] Thomas, *Quart. Journ. Geol. Soc.*, vol. lviii, 1902, p. 620; ibid., vol. lxv, 1909, p. 229.

[2] Besides the papers cited in the previous note the chief publications on this subject then in existence were Sorby's Presidential Addresses to the Geological Society, 1879–80; Bonney's Address to Section C, British Association, 1886; the work of Retgers on the dune sands of Holland; and a few others.

[3] *Proc. Camb. Phil. Soc.*, vol. xvii, 1913, pp. 132, 161.

[4] Geol. Mag., Vol. LVI, 1919, p. 211.

1. Panning and Economy of Heavy Liquids.

One of the chief drawbacks to work on the separation of minerals by means of heavy liquids has always been the great expense involved, and of late years this has become very serious. In order to avoid this difficulty as much as possible, it is desirable, before proceeding to detailed investigations, to carry out a preliminary examination to ascertain what minerals are present and in approximately what quantity. In some samples heavy minerals are scarce, and if large quantities of sand are simply dumped into bromoform, for example, a great loss of expensive liquid is not to be avoided. Hence some form of preliminary concentration is most desirable unless the worker can afford to work regardless of expense, which few can now do, unless enjoying the benefits of rich endowments or unlimited access to public money. In respect of economy of method petrographers could learn much from ore-dressing practice.

A preliminary concentration is most easily carried out in most cases by means of panning, the only requisites being a 9-inch porcelain evaporating dish and a little skill on the part of the worker. With care and practice panning can almost be made a quantitative method, and at any rate for the comparison of different samples fairly accurate and very useful results can be attained, even when the specific gravities of the heavy and light groups of minerals do not differ by more than 10 per cent. The advantages of panning for concentration of really heavy minerals, such as gold and platinum, cassiterite, and even monazite, are obvious and do not need elaboration. But a point of great importance is this, that unless some form of concentration is used, there is great risk of missing the rarest and sometimes the most interesting constituents. If it is desired to make sure of finding all the minerals of a sand, it is well to pan a large quantity in several instalments, not carrying the process too far at first, then adding together all the partial concentrates for a final panning carried out with special care. This method is also applicable to field-work, if special or rare minerals are being sought for in a particular area. Panning on the spot will thus avoid carrying home large quantities of material. For this purpose a metal pan has obvious advantages. Of course, in such a case a normal unconcentrated sample must also be taken if quantitative work is in view. Another advantage possessed by large concentrates obtained in this way is that chemical tests can often be applied to them on a reasonable scale. The usefulness of this method for field-work is, of course, limited by absence of water in many localities.

2. Grading of Material.

In this connexion there are two points in need of discussion and elucidation ; firstly as to methods to be employed, and secondly as to definition of standard sizes and nomenclature of the grades.

For the separation of loose material there are three classes of methods commonly employed, differing somewhat in scope and

application: these are: sieving in the dry state; subsidence in water; and the so-called elutriation. All of these deal merely with size of grain regardless of mineral character and other properties. Almost the whole of the valuable and important work carried out of late years by soil-workers has been done by subsidence in water, sieving being employed for the removal of the coarser fractions. In this line of work both methods and grade-limits are thoroughly standardized and well established. To the agriculturalist the finer grades of material, fine sand, silt and clay are of the greatest importance, and he is less concerned with the constitution of the coarser material as distinguished from its amount. The petrographer, however, is more interested in those grades whose mineral character can be determined microscopically. In fact, no method has yet been devised for dealing with the mineral constitution of the finest fractions. These two classes of workers, therefore, have somewhat different aims. In some classes of economic investigation, however, both mineral constitution and size of grain are important, as for example in the examination of glass sands, where evenness of grain and absence of heavy resistant minerals are both desirable.

Of late years workers on these lines have pinned their faith largely on elutriation, or hydraulic classification. The leading principle here is grading by suspension in an upward current of water. Now it is obvious that the behaviour of a mineral grain in such circumstances is conditioned by two factors, the size and the density of the grain: it is in the simplest case a function of two independent variables. No doubt also surface tension here also comes into play, and indeed the phenomena of flotation as applied to ore-dressing show that the character of the surface with regard to wetting is of the utmost importance. Now, obviously, apart from the question of flotation, a large grain of low density may have the same weight as a small grain of high density, and here surface area also comes into play. The effect of this can be seen in the behaviour of flakes of mica in natural deposition or in panning. Mica usually behaves as a light mineral and sinks slowly in moving water, although its density may be as high as 3·1. Again, the free surface of a mineral is by no means directly proportional to its weight. For example, a flat flake of mica possesses a very large surface in proportion to its weight, and if its thickness, and therefore its weight, is doubled, the increase of surface may be infinitesimally small. Taking all these points into consideration, it is difficult to see how elutriation, as usually practised, can give any results of real value in the case of mixed sediments containing a variety of minerals of different sizes, densities and surface properties. The method is undoubtedly of very great use in grading samples of uniform or nearly uniform mineralogical composition, but in the case of ordinary mixed sands and silts the product must be a heterogeneous collection of grains of all sorts of shapes and sizes of varying densities and mineral characters.

With regard to the use of sieves and wire-woven screens, this is

undoubtedly the simplest and easiest method of grading samples of a fair degree of coarseness. By some recent writers, however, the use of fine screens has been rather strongly condemned, as the writer believes, on somewhat inadequate grounds. For satisfactory results it is of course true that good and well-constructed screens of accurate gauge must be used. It is hardly necessary to discuss here the importance of fine screening in ore-dressing, where wire-gauze as fine as 200 meshes to the linear inch is commonly used on a large scale. Few geologists seem to be aware of the high degree of perfection now attained in the manufacture of such screens.

With regard to size-limits and the nomenclature of the different grades, it is very unfortunate that so many different standards are in use. Thus agriculturalists have one scale, mining men another, while each petrographer seems to adopt a different one for himself. It is highly desirable that some general agreement should be reached, but it is impossible to discuss so complex a matter at length on this occasion.

3. Dark-ground Illumination.

During a considerable number of years largely devoted to research on the composition of detrital sediments, and in further work on the accessory minerals of the igneous rocks, the writer has been accustomed to place great reliance on methods of dark-ground illumination for the identification of minerals under the microscope. In a paper published about ten years ago, in a journal not usually consulted by geologists,[1] an account was given of a simple method of illumination, applicable both to dark ground and transmitted light, enabling the change from one to the other to be effected almost instantaneously. Since this has never, so far as the writer knows, been referred to by any author, and is probably still quite unknown, no apology is offered for a somewhat lengthy quotation from the paper referred to.

"The heavy residues from all the sands dealt with contain a considerable proportion of opaque grains, all of which look very similar when examined by transmitted light in the usual way. Hence it became highly desirable to devise some method by which grains of different colours could be readily distinguished. It was important also to make such an arrangement that it was possible to revert to the normal method of examination without disturbance of the microscope or of the slide, enabling any individual grain to be examined by each method alternatively. After some trials it was found that the best results were obtained by strong oblique illumination and that various colours of background were required for objects of different characters. Thus highly-coloured transparent or semi-transparent minerals are made most conspicuous by a black background, while for completely opaque and metallic grains a partially illuminated background gives the best results. The method finally adopted was as follows: a powerful electric lamp was

[1] *Proc. Cambridge Phil. Soc.*, vol. xvii, 1913, pp. 161–7.

placed to one side of and as close as possible to the revolving stage of an ordinary Swift petrological microscope, the light being raised very slightly above the plane of the stage. The illumination of the field of view is thus very nearly horizontal. The plane mirror of the microscope is arranged to reflect a beam of light up the tube in the usual way for examination by transmitted light, with or without the nicols. To obtain a dark background all that is necessary is to insert a card of the required shade, black, white or grey, into the space between the lower nicol and the stage. It is convenient to have a single card, half black and half white, or with a grey strip in addition: this card can be moved about as required for different grains, and it can also have a hole cut in it to be brought to the centre when an opaque background is not desired. This card in no way interferes with the working of the nicols, the revolving stage or other parts of the microscope, and can be left in position permanently. This method of examination is specially useful for the detection of glauconite, magnetite, haematite, or any metallic minerals. . . . The special advantage claimed for this arrangement depends on the extremely oblique illumination, which reveals clearly pittings and inequalities on the surfaces of the grains, thus bringing out the characteristic appearance. Among transparent minerals it can be usefully employed for the detection of thin flakes of mica, which always lie flat in properly mounted slides. Since the light strikes them edgeways, owing to their thinness they are practically invisible against the dark background, though conspicuous when viewed by transmitted light. This complete disappearance of a mineral may be taken as a proof of its occurrence in very thin flakes. By this means also the colours of very minute grains are made easily visible."[1]

Further experience has shown that this method of illumination is almost indispensable in the investigation of residues containing minerals with metallic lustre, as well as in the discrimination of the different oxides of iron, leucoxene, and other opaque substances of somewhat indefinite character such as are so common in many highly oxidised deposits. Some difficulties that arise in connexion with these are discussed in the next section.

4. Further Methods of Research.

The following section is of a frankly speculative character and does not profess to give any tangible results of work accomplished. It is rather in the nature of a theoretical discussion of some difficulties that have been met with and suggestions as to possibilities for the future.

Everyone who has worked on loose sediments or on crushed rocks is well aware that it is as a rule impossible to identify all the constituents of a given sample. In nearly all cases the finest material, the mud or clay fraction, is removed before any attempt at mineral separation is made. This is in itself unsatisfactory, but, as

[1] Op. cit., pp. 162–3.

before mentioned, no real remedy is as yet known. It is notoriously difficult to apply the ordinary optical tests to very minute grains under a high power, even in the case of transparent minerals, and with opaque grains very little can be done. Even among the larger grains there are nearly always to be found such unsatisfactory subjects as the iron oxides in their many varieties, leucoxene, glauconite in various stages of alteration, metallic sulphides and small chips of fine-grained rocks. The iron oxides are often of secondary origin and frequently form merely a coating on grains of some other mineral. These can be removed by electro-magnetic separation, or as a rule by acid treatment; neither of these processes is altogether satisfactory, and it is certainly not justifiable, as recommended by some authorities, to begin by treatment with strong acid as a preliminary, before any actual methods of determination are applied.[1] This is bound to result in solution or alteration of some minerals. Thus for example apatite is readily soluble in hydrochloric or nitric acid: the presence of this mineral in a sand is often a point of considerable interest. Magnetite also is quite easily soluble in dilute acid. In every case some effort should be made to determine the character of as many grains as possible in a sample mounted before any acid is used. The writer's practice is to mount a portion of the panned residue or that from the heavy liquid without any acid treatment, and then to clean the remainder or another similar concentrate with acid. For the determination of opaque grains micro-chemical tests may be applied to the panned concentrate, and here also dark-ground illumination will be found of the greatest value.

In dealing with opaque grains it is important to find out to what extent the apparent grains of iron oxide are solid, or whether they are merely pellicles of decomposition and oxidation products on grains of some other mineral. It is often found that concretions and rounded grains of oolitic type leave on treatment with acid siliceous skeletons, which may be objects of great interest.[2]

One of the minerals that gives the greatest amount of trouble in sands is glauconite, since its appearance varies greatly, as well as its density, according to the degree of oxidation that it has undergone. It is often found that glauconite occurs in both the heavy and light fractions from a panning or from a heavy liquid separation, according to the amount of alteration. The decomposition of this mineral is a point of much importance in the study of soils, owing to its considerable potash content, at least in some varieties.[3] The problem of the decomposition and alteration of glauconite is much in need of study, since the writer's observations suggest that these

[1] See, for example, Milner, *An Introduction to Sedimentary Petrography*, London, 1922, p. 19.

[2] See, for example, Stead's admirable researches on the constitution of the oolitic ironstones of Cleveland, illustrated by beautiful photographs. *Proc. Cleveland Inst. Eng.*, 1910, pp. 75–107.

[3] Hallimond, *Min. Mag.*, vol. xix, 1922, pp. 330–3.

changes are highly complex and variable according to conditions. At any rate it is clear that many of the grains of iron oxide in sands of all ages were originally glauconite. It is well known also that this mineral is commonly associated with phosphates, but the occurrence of phosphates, apart from crystalline apatite, in sands does not seem to have been investigated.

There are undoubtedly many other points connected with the opaque minerals that will eventually be worked out as the subject progresses, but owing to considerations of space it is only possible to deal briefly with one other, namely, the determination and separation of sulphides in sediments. Not long ago the author had occasion to examine a sample of London Clay. All clays are difficult to deal with, but this was specially so owing to its excessive stickiness when wet. Eventually, however, after interminable washings a residue was obtained sufficiently clean for bromoform separation. This was found to consist almost entirely of minute concretions and small crystals of iron sulphide, probably marcasite. This afforded a most useful criterion for distinction from certain other clays and brick-earths, with which the London Clay had been confounded in that particular locality. The sulphide in this case was certainly authigenic. Pyrite is known to be abundant in many of the older sediments and marcasite is also common, e.g. in the Gault. Pyrrhotite is less common in sediments, but apparently exists in some of the older well-cemented sandstones, while galena, blende, and chalcopyrite occur locally. The point that it is desired to raise here is as to the possibility of the application of some form of froth or oil-flotation to the concentration of these sulphides. This of course can be done on either a large or a small scale if the sulphides are abundant: of this there is no doubt, as witness the vast operation of the various flotation processes of ore-dressing. The object here is to find a suitable technique and medium for the flotation of very small amounts of sulphides in crushed sediments, and research is also needed as to the possibility of separating oxides and non-metallic minerals by flotation, either simple or differential.

5. The Primary Sources of Heavy Minerals.

Finally, to bring these somewhat rambling notes to a close, a few words may be said as to the uncertainty that still prevails as to the sources of many of the most common minerals of sands. It is of course obvious, and beyond doubt, that many mineral grains are so hard and stable that they pass on from one formation to another, through successive cycles of denudation and deposition, with little change. The discovery of a certain mineral in any particular deposit is no proof that rocks containing that mineral as a primary constituent were exposed at the time of formation of the deposit. In many instances they are derived at second hand from some older sediment, and the wear and tear in really hard and stable minerals may be very small indeed. In other cases, however, where the

minerals are either soft or unstable it is quite otherwise. The question of andalusite in sediments has been often discussed, with no very definite result, though it appears probable that this mineral will not stand much weathering and transport. On the other hand, kyanite appears to be very stable: its great abundance in British sediments is nevertheless somewhat of a puzzle: it is very scarce in Britain, except in the Highlands, and it is difficult to explain its abundance in so many Mesozoic and later sediments of coarse texture when the necessarily long transport is taken into account. Perhaps it travelled south in two main stages, first into the Millstone Grit and Coal Measure Sandstones, and then into the Jurassic and Cretaceous.

In the great majority of sediments the most abundant transparent heavy minerals are zircon, rutile, tourmaline, kyanite, staurolite, and garnet. Let us for a moment consider the possible source of one of the commonest of these, namely, rutile. This is almost universal in its occurrence and shows a good deal of variation. For a long time past the author has been anxious to obtain some information as to the origin of this, so far with very little success. Some of the smaller and sharply angular crystals occasionally seen are probably formed in situ, by decomposition of ilmenite or other titanium minerals, as anatase certainly can be, and occasionally brookite. But it is difficult to apply this idea to the large and obviously well-rolled prisms and grains of rutile that are so common everywhere in all classes of sediments, from the Jurassic upwards, at any rate, which is as far back as personal investigations have extended. These grains show every possible degree of angularity and rounding even in the same sample, and the vast majority of grains of rutile have clearly been derived as such: whether from older sediments, from metamorphic or igneous rocks is not known. Much time has been spent both in a search of descriptive petrographic literature and in the crushing and separation of rock samples of all kinds, chiefly metamorphic and igneous, especially from Scotland and Scandinavia, but hitherto without result: the primary source of the rutile has not been traced. It is rare to find this mineral in thin sections of rocks of any kind, except sediments. It may have arisen by decomposition of titaniferous iron ores in some of the earlier semi-metamorphic sediments: it is certainly not authigenic as a rule in later formations. This is an example of the kind of problem that must be attacked and solved before the petrography of the sediments can be considered to be on a satisfactory footing.

REVIEWS.

IRON ORE: PART I, UNITED KINGDOM; PART II, BRITISH AFRICA; PART III, BRITISH AMERICA; PART IV, BRITISH ASIA; PART V, AUSTRALIA AND NEW ZEALAND; PART VI, EUROPE AND AFRICA (FOREIGN); PART VII, FOREIGN AMERICA; PART VIII, FOREIGN ASIA. Imperial Mineral Resources Bureau, 1922.

THE various parts of this useful publication have been appearing at intervals for several months past, but it was considered advisable to await the last part so as to review the work as a whole. As stated in the general introduction, the preparing of this large and comprehensive account of the iron-ore resources of the world has been rendered practicable by financial assistance given by the National Federation of Iron and Steel Manufacturers. This body is much to be congratulated on its public-spirited action.

The scope of the work is largely indicated by the titles of the separate parts, and here, as a preliminary, we have a bone to pick with the scheme adopted for the divisions of the subject. To a geologist it would have seemed much more natural to divide the work into five parts, one for each continent. A continent at any rate is a natural unit, whereas an empire is not. Anyone who has of late years had much to do with obtaining information as to the distribution throughout the world of any mineral product will sympathize with our complaint: the usual state of the case is, as to the British Empire a superabundance of information; for the rest of the world quite the reverse. In some instances the Imperial arrangement becomes an absurdity. For instance the Malay Peninsula from Burma to Singapore forms a coherent geological unit with similar mineral productions throughout; it is mostly British, but, most unfortunately, a small strip of Siamese territory stretches right across the middle. This is treated in an entirely different section of nearly all books of reference, leading to a break of coherence in the treatment of the subject by the writer and loss of time on the part of the reader. This is only one instance among many, and is not in reality founded on an examination of the particular book under review, but it will serve as a concrete example. The net result is that the economic geologist in search of information of scientific value gets annoyed with the British Empire in particular and with political boundaries in general. This objection will of course appeal with much less force to the commercial and industrial public, for whom this compilation is primarily intended. Nevertheless, we maintain that the objection is sound, and the method of arrangement here selected is clumsy, some of the titles, such as "Foreign America", reading very oddly.

The first volume contains an admirable summary of the present state of information as to the iron resources of the British Isles,

largely compiled, with full acknowledgment, from the well-known publications of the Geological Survey and of Dr. Hatch. These have recently covered the ground so completely that it would not be natural to expect much that is new. The estimates of reserves appear to be compiled on a conservative basis; the least satisfactory feature here, as elsewhere, is with regard to the enormous tonnage assigned to the possible reserves in the Coal-measures of South Wales: the ore is doubtless there, but it seems highly improbable that it will ever be worked, taking into account the attitude of labour and the general trend of industrial development. A truer estimate of the British resources would probably be attained by writing off this item altogether as belonging to a very dim and distant future. One could wish that some of the authors of textbooks of geography intended for consumption in schools would study the actual figures of output by districts as summarized in Dr. Hatch's table on page 28. This would effectually dispose of the hoary myth still lingering in these books as to the indissoluble geographical connexion between coal and iron in this country. It would be interesting to know what percentage of teachers of geography are aware that Northamptonshire is the second largest producer of iron-ore among the English counties, and Lincolnshire third, while the coal-fields are responsible for only 8 per cent of the total.

Turning next to the European continent (Part VI) there is a very well-written and interesting account of the great Lorraine iron-field, which has constituted, and still constitutes, so important a factor in European politics. The almost complete dependence of the German iron and steel industry on this field is well brought out, with the complications introduced into its further development in French hands by the question of coking coal. For the sake of the future of European industry and the continuance of civilization in the Old World some solution of this problem must be found, and that soon. The influence of basic steel on the history of the world is a subject for treatment by the historians of the future.

Petrologists will turn with interest to the accounts here given of the great magnetite deposits of Sweden, and especially those of the far north in the district now generally called Kiruna, for convenience. These appear to be, as described by the Swedish geologists and by Professor Daly, the most striking examples of magmatic differentiation that the world has to show, and their practical importance is quite on a par with their theoretical interest. The investigation of such ore-bodies has also shown the great value of magnetic surveys in connexion with iron-ores, a subject largely developed in Sweden and North America and now attracting attention elsewhere on a large scale.

Among the newer European countries it appears highly probable that Czechoslovakia will shortly take a leading place as a producer of iron. Its resources both in ore and in coal are large, and now that the industry is largely free from German control it should go ahead.

Even now there are large and modern steel-making plants in operation, and the people seem determined to make a success of their new republic, which apparently possesses greater elements of stability than some of the other creations of the Peace Treaty.

Turning now to the American continent, we find in these volumes a good account of the Lake Superior and Birmingham districts of the United States and the Wabana ore of Newfoundland, all of the utmost importance, but often and well described in many easily accessible publications. With regard to the future, the most interesting subject for speculation is with regard to the economic possibilities of the enormous tonnage of high-grade iron-schists known to exist in Brazil. From all accounts, this may prove to be the world's greatest ore-reserve, but its development is at present hindered by distance from the coast, lack of coal, and an inadequate railway system. An average of 89 analyses of these ores from the State of Minas Geraes gave 69·65 per cent of metallic iron and 0·0125 per cent of phosphorus. Thus the ore is very nearly pure haematite. Many of the Brazilian ores are, however, more phosphoric than is generally supposed. Possibly, in no very remote future the development of the water-power resources of S.E. Brazil may lead also to the establishment of an extensive electric iron-smelting and steel-making industry: this seems to be the most hopeful prospect for the development of the undoubtedly vast resources of that country. In point of fact, a beginning has now been made in that direction in the State of São Paolo.

It is impossible in the space at our command to discuss at length the many other points of interest raised by these admirable volumes. We can only mention briefly that there are prospects of the establishment of a successful steel industry in the Union of South Africa, works being now in operation or in course of construction at Vereeniging, Pretoria and Dunswart in the Transvaal, and at Newcastle, Natal. The products will be almost entirely consumed locally, as an extensive export trade is considered improbable and the demand in the country itself is large and likely to increase.

In Australia a new phase of the iron industry set in with the establishment of the Broken Hill Proprietary Company's works at Newcastle, N.S.W., in 1915, entailing a capital expenditure of over four millions, including plant, at Iron Knob, South Australia, whence the ore is obtained. However, it must be remembered that Australian mining ventures are nowadays always in a precarious condition owing to labour troubles and the strange economic theories sometimes propounded by the State Governments. The general policy of the Federal Government nevertheless is in the direction of encouraging the development of Australian industries, and this has been accentuated by revelations during the war as to the extent of German commercial penetration in that continent.

In conclusion, we should like to say that this work has been eagerly looked forward to by all those interested in the iron industry

from whatever point of view, either scientific or commercial, and the high anticipations formed have been well realized. It is a mine of information, well put together, and as readable as a largely statistical production can be. It will prove of the utmost value for a long time to come.

R. H. RASTALL.

GEOLOGY OF THE TERTIARY AND QUATERNARY PERIODS IN THE NORTH-WEST PART OF PERU. By T. O. BOSWORTH. With an Account of the Palæontology by HENRY WOODS, T. WAYLAND VAUGHAN, J. A. CUSHMAN, and others. 8vo. xxii+434 pp. Maps and numerous illustrations. London: Macmillan and Co., Ltd., 1922. Price, 45*s*. net.

THE region described in this work comprises a long strip of desert country between the Cordillera and the coast of Peru, from 15 to 40 miles in width. In this region Dr. Bosworth spent several years (1912–18), during which he not only mapped some 4,000 square miles of country, but also unravelled its geological history in a masterly manner.

The older rocks, on which the Tertiary deposits rest, range in age from Archæan to Cretaceous, and were uplifted in pre-Tertiary time forming the Cordillera. During the Tertiary period these mountains formed the western margin of the South American continent. The Tertiary rocks are all of shallow water origin, and consist of clay, shales and sandstones of enormous thickness (estimated at 15,000 to 25,000 feet), indicating a long-continued period of subsidence; afterwards there was an elevation of 5,000 to 10,000 feet, as shown by the present altitude of the strand lines of the Tertiary beds along the mountain flanks. The Tertiary rocks are traversed by a network of faults, by which they are cut up into innumerable separate blocks —the whole resembling a gigantic crush-breccia. The faults range from mere fractures up to master-faults some miles in length with a throw of several thousand feet.

The Tertiary deposits are divided into three main groups:—(1) the Negritos Formation, (2) the Lobitos Formation, (3) the Zorritos Formation. The first two are of Eocene age, the last is Miocene. The fossils from these deposits are illustrated by 24 plates,[1] mainly from drawings by Mr. T. A. Brock. The Mollusca and Decapod Crustacea are described by Mr. Henry Woods, the Corals by Dr. T. Wayland Vaughan, the Foraminifera by Dr. J. A. Cushman, and an Echinoid by Prof. H. L. Hawkins. The Negritos Formation is regarded as of Lutetian and Auversian age; its fauna is abundant and consists largely of gasteropods and lamellibranchs. Most of the species are not known from other regions, but some resemble species found in the Eocene of the Eastern and Gulf States of America,

[1] The plates have also been published separately under the title of *Illustrations of the Tertiary Fossils of Peru*, Macmillan & Co., April, 1922, price 5*s*. net.

indicating interoceanic communication between the Pacific and the Atlantic; whilst a few are of interest in their resemblance to species found in the Middle Eocene of Northern Italy and North Africa. The Lobitos Formation contains fewer fossils, those of the lower 1,000 feet closely resembling the Negritos forms; but at higher horizons there is much greater difference in the faunas.

The most fascinating part of Dr. Bosworth's work is that dealing with the Quaternary history. The deposits, known as Tablazos ("table-lands"), are raised sea-floors with a smooth surface and gentle slope; they extend inland from 10 to 20 miles and consist of from 5 to 250 feet of shell-limestones, calcareous sandstones, and pebble beds, with beaches at their inland margins. The oldest of the Tablazos—the Mancora—has now an elevation of 200 to 1,200 feet, and still covers 700 square miles of country. The Talara Tablazo stands at 100 to 350 feet above sea-level, and the youngest Tablazo—the Lobitos—is at 50 to 110 feet.

The Tablazos are the result of repeated oscillation of this part of the earth's crust. There was first a gradual subsidence, during which the sea advanced on the land and carved out a plain of marine denudation. While this was going on, sediments were deposited on the plain as it sank below the limit of marine erosion. Afterwards these deposits were uplifted above sea. These processes were repeated at least three times, giving the succession of Tablazos mentioned above. At the present time a movement of uplift is in progress, but it has not yet amounted to more than 10 to 15 feet.

Fossils are abundant in the Tablazos and consist mainly of mollusks and barnacles. The former have been identified by Col. A. J. Peile, the latter by Mr. T. H. Withers. All the species are still living. The faunas of the two older Tablazos are practically identical, but the Lobitos Tablazo contains many additional species due to a change in the geography of the coast-line which affected the course of the Humboldt current, resulting in the appearance of a larger proportion of warm-water species.

The Mancora Tablazo probably did not extend far west of the present coast-line, on account of the great depth of sea found quite near the coast, the 1,000-fathom line being only 15 miles distant, and the 2,000-fathom 27 miles from the coast. The continental shelf is only 4 to 20 miles in width, its border being at about the 100-fathom line, beyond which the sea-floor descends steeply to 2,000 fathoms. The shelf has thus a precipitous edge, the descent being 2,400 feet in a mile; so that there is really a submarine cliff which, however, does not follow the irregularities of the coast, but is more nearly straight. Dr. Bosworth suggests that this cliff is a great fault-scarp, marking the main fracture at which the Tablazos region was repeatedly lowered and raised.

Before the uplift of the Mancora Tablazo the torrential rivers from the mountains flowed straight into the sea; after the uplift they poured on to a plain and deposited an enormous breccia fan over the

Tablazo and extending back into the valleys. Soon the rivers cut down through this until they reached their base-level. Similar downward erosion, leaving terraced valleys, occurred after the formation of the other Tablazos.

In Part IV a valuable account is given of the desert conditions and the processes of erosion and deposition, which should appeal to the geographer and traveller no less than to the geologist.

The last part of the book describes the oilfield: its history and output; the relation between the geology and the occurrence of petroleum, and the origin of petroleum.

Dr. Bosworth's investigations were done under the trying conditions of life in an equatorial desert. His results are of such far-reaching importance, and so clearly expressed, that students, as well as teachers, may read his book with pleasure and profit.

REPORTS AND PROCEEDINGS.

Congress of the German Mineralogical Society at Leipzig.

14th–16th September, 1922.

At the opening meeting, with F. Becke in the chair, an obituary notice of Dr. Th. Liebisch was read by Professor A. Johnsen.

F. Rinne: The physico-chemical basis of crystalline structure. The author gave a brief résumé of the history and recent development of crystallography since the famous discovery of Laue and subsequent work done by W. H. and W. L. Bragg, Debye, Scherer, and others. He pointed out that this new department of science, the study of the crystalline structure by means of X-rays, is a solid foundation stone to a wider science, and for it he proposed the name of Leptology, which means the science dealing with the study of aggregation of elementary particles of matter.

H. Grimm: The relations between the crystalline structure and the atomic ions. Basing his work on the ideas of Bohr and Kossel, the author gave a scheme of a periodic classification of atomic ions and discussed the questions of complex molecular ions and crystalline structure. The isomorphous minerals were treated by the author with particular care. This work on atomic ions and the calculation of their radii seems to be supplementary to the researches of H. L. Bragg on atomic radii.

During the discussion raised by this paper, P. Niggli pointed out the difference existing between the conception of a static and a dynamic model of atoms, and on the relations between the crystalline and intra-atomic structures.

N. Gross: The number of centres of crystallization as a function of volume, time, and under-cooling of a melt.

In this paper the author presented very interesting results of observations on the number of centres of crystallization in a cooling liquid. The application of these results to the study of magmas would be of great value in geochemistry.

O. Mügge: The influence of pressure and temperature on the crystallization of melts.

A. Schwantke: The influence of gases on the differentiation and crystallization of magma.

Besides the above-mentioned paper, a number of communications dealing with physico-chemical and optical properties of minerals were read, as for example:—

E. Schiebold: X-ray rotation spectrograms.

F. Becke: On some optical properties of biaxial minerals.

H. Steinmetz: On the law of Tschermak.

H. Steinmetz: The crystalline forms of ice.

W. Eitel: The system $CaCO_3$–Ca_2SiO_4, illustrated by contact minerals.

A. Johnsen: On double salts and mixtures.

W. Maucher: Aggregation of minerals.

L. Milch: A general survey of the question of differentiation.

In this paper the author gave a very good summary of the whole history of this controversial question, and set out the recent advances and prospects. He pointed out that this question up to the present was treated by different writers from their subjective, and rather one-sided point of view, and only now do we begin to acquire a more synoptic and broader view on the processes of differentiation and petrogenesis. Thanks to the American geochemists, we have now at hand a series of facts illustrating the actual process going on during the cooling of silicate melts. The application of these results to the study of rocks in the field may lead to excellent results.

V. M. Goldschmidt: Genetic types of igneous rocks.

The latest work of American geochemists, particularly Bowen, leads us to the conclusion that the mineralogenesis in a cooling magma is not entirely regulated by the eutectic proportions, but by a complex changing equilibrium between the solid phases and the liquid residue. Taking this into consideration, the author thinks that the experimental results of the American school will provide the necessary means for the construction of a genetic classification of igneous rocks, or in any case, in the first instance, will allow us to find some genetic relationship between certain types of rocks. Having this object in view, the author presented a generalized scheme of genetic relationship between different types of magma and also a genetic table of the Norwegian series of rocks.

E. Lehmann also gave a paper on the petrogenesis of alkaline magmas in the light of Bowen's reaction principle, and presented some striking cases of rocks having a different mineral composition but of the same chemical type. He emphasized the importance of a knowledge of the cooling history of a given series of rocks, and gave some examples of reaction-equilibrium between different minerals, as a function of external physical conditions.

P. Niggli gave another paper on the same subject.

F. Becke: Differentiation in the central gneiss of the High Tatra.

By means of numerous chemical analyses, the author proved that all the gneissic massives are composed of orthogneiss and are not of sedimentary origin, as was previously supposed. The application of a graphic method or modified triangular diagram of Osann proved to be very successful.

O. Erdmannsdoerffer: Differentiation and mineral vein formation in the Harz.

The field work done by the author in the region of the Brocken massive revealed the geological history of the igneous intrusions, and led to the support of the absorption theory of Loewinson-Lessing and Daly. The differentiation of a deep-seated origin proceeded from the basic to the acid phase.

E. Kaiser: Differentiation and assimilation in the syenite of South Namib, South-West Africa.

The work of Kaiser also lends support to the theory of assimilation. The absorption belt, composed of a more basic rock and situated along the contact of syenite and dolomite, was studied by the author in all its details.

Besides these papers, O. Mügge gave an account of his work on miscibility at high temperatures, and K. Mieleitner on the minerals of pegmatite veins.

H. Schneiderhöhn read a report on his investigation of ore minerals under the microscope.

After the Congress, under the leadership of F. Rinne and E. Schiebold, two excursions were arranged in the Granulite Mountains of Saxony. S. Tomkeieff.

Liverpool Geological Society.

17*th October*, 1922.—The President (Professor P. G. H. Boswell, O.B.E., D.Sc., F.G.S.) in the Chair.

The President delivered his Annual Address on "Some Aspects of the Petrology of Sedimentary Rocks".

A general review of the state of knowledge of this branch of Geology, particularly from the standpoint of the mineralogical constitution of sedimentary rocks, showed that the history of development could be divided into four periods, characterized by (1) investigation of recent sediments, the work being purely descriptive in character; (2) investigation of ancient sediments, still descriptive, but with the suggestion of possible determination of the source of constituents; (3) intensive work upon sedimentary rocks, with deductions regarding source of material, drainage conditions, and details of palæography; (4) attempted correlations over limited areas, based on mineralogical constitution, and inferences regarding tectonic history. The work of various investigators in this field since 1858 was reviewed and a general analysis of the results achieved was submitted. A summary of the petrography of the succession